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CONTRIBUTION

TO THE

SURFACE ANATOMY OF THE CEREBRAL HEMISPHERES

By D. J. CUNNINGHAM, M.D., D.Sc. (Dubl.), F.R.S.

WITH

A CHAPTER UPON CRANIO-CEREBRAL TOPOGRAPHY

By VICTOR HORSLEY, M.B. (Lond.), F.R.S.

With Eight Plates.

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CORRIGENDA.

Page 10, last line in the table, *read* "three and a-half months" *for* "four and a-half months."

,, 17, line 7, *read* "eleventh to the twelfth week" *for* "thirteenth to the fourteenth week."

,, 53, ,, 3, *read* "five and a-half months" *for* "six and a-half months."

"CUNNINGHAM MEMOIRS."

No. VII.

CONTRIBUTION TO THE SURFACE ANATOMY OF THE CEREBRAL HEMISPHERES BY D. J. CUNNINGHAM, D.Sc. (DUBL.), F.R.S. WITH A CHAPTER UPON CRANIO-CEREBRAL TOPOGRAPHY BY VICTOR HORSLEY, M.B. (LOND.), F.R.S. (PLATES I. TO VIII.)

[Read APRIL 14, 1890; FEBRUARY 8, 1892.]

INTRODUCTION.

IT is strange that the Surface Anatomy of the cerebral hemispheres, offering as it does a field of work apparently so limited and circumscribed, should still be found capable of yielding rich results to the earnest investigator. But such is indeed the case notwithstanding the great advances that have been made in Cerebral Anatomy during the present century, and more especially during the last fifty years. The labours of Leuret, Gratiolet, and Broca in France, Huschka, Bischoff, Pansch, and Ecker in Germany, and Huxley, Turner, and Flower in this country, have chiefly contributed to the rapid progress which has been made in this direction within the time specified. The descriptive anatomy of the surface of the adult human cerebrum is now very nearly complete; what still remains to be done is the establishment of our knowledge upon a proper morphological basis.

In approaching this aspect of the subject from the phylogenetic point of view we find an immense amount of material ready for use. The simian brain has been studied almost as closely as that of man.

9i 1

Further, the facts acquired in this manner have been compared, checked, and amplified, by the evidence afforded by ontogeny. It must be admitted, however, that in the case of the primate brain this evidence is somewhat one-sided. Very little is known of the manner in which the fissures and gyri make their appearance in the fœtal ape. In so far as the human brain is concerned the material is very abundant, but the picture afforded is so variable that very different interpretations may be arrived at by different observers. It cannot be too strongly insisted on, that it is only by the close study of large numbers of developing brains in each stage of growth that correct and trustworthy information can be gathered; and seeing that the development of the permanent fissures is for the most part compressed into the last four months of intra-uterine growth, there should be little difficulty in meeting this requirement.

It was my intention when I began this investigation to make a special study of the entire cerebral surface of the primate brain; and taking up each fissure and gyrus in turn, I had purposed tracing its history through every stage of its development and growth. I very soon ascertained, however, that such a task would require many years to accomplish, and, as it was necessary to produce this Memoir within a reasonable time, I was reluctantly obliged to abandon my original plan of work. I have therefore restricted my investigations to certain of the more important fissures, but I have endeavoured to elucidate the anatomy of these from every point of view—the morphological as well as the topographical. In the pursuance of this inquiry the questions which I have specially sought to determine are the following:—

1. What is the more usual mode of development of the selected fissures? At what period of life do they attain their fully-formed condition, and what light does the whole process of furrow-formation throw upon questions relating to the general growth of particular areas of cerebral cortex?

2. Do the fissures undergo any change of position on the cerebral surface after they have once been laid down; and are the changes which we know occur in the relations between the fissures and the cranial sutures at different periods of growth produced by an increase or a decrease of

certain districts of cerebral surface, by a want of harmony in the growth-rate of the different cranial bones, or by these influences acting together?

The results which I have obtained are given in the first five Chapters. Each of these is more or less complete in itself in so far as it represents an independent piece of work, which was finished, and, in the case of the earlier Chapters, printed before the succeeding Chapters were commenced.

The last Chapter is the work of Professor Victor Horsley. It deals with the Cranio-Cerebral Topography, and I consider myself fortunate in being able to incorporate in this Memoir so valuable a contribution on a subject of such vital importance to all interested in the advance of cerebral surgery.

Material.—For more than four years I have been collecting material for this work. The following is a list of the cerebral hemispheres which I have had at my disposal:—

Period of Growth.	No. of Hemispheres.	Period of Growth.	No. of Hemispheres.
From the end of the second month of development up to full time,	104	Children, four to five years,	14
Full-time fœtuses,	24	Girl, eleven years old,	2
Children, three months,	6	Boy, twelve and a-half years old,	2
Children, six months,	4	Youth, fifteen years old,	2
Children, twelve months,	4	Adults,	82

In so far then as the developing fœtal brain is concerned my material has been very abundant. The same also may be said for the adult brain, because the number 82 in the above Table merely refers to those hemispheres which I have specially prepared for measurement. In dealing with other points many additional adult hemispheres were available. The list shows a great deficiency in the brains of children.

Methods employed.—Certain of the questions involved in this inquiry could only be elucidated by careful measurements of the cerebral surface at different periods of growth. To obtain these with any degree of accuracy it was absolutely necessary that the natural configuration and shape of the cerebral hemispheres should be preserved in every detail. Anyone may satisfy himself that the most different measurements may be

obtained from the same brain when examined under different conditions. The success of an investigation of this kind mainly depends on the methods employed.

As a rule the different observers who have endeavoured to determine the position of the various cerebral sulci, have each adopted a method of his own. In France, Broca's* plan of introducing pegs through the cranium at certain well-defined points on the surface of the calvaria has been almost universally adopted. Bischoff† independently employed the same means. Turner‡ and Hefftler§ examined the brain *in situ*—a proceeding which is certainly very much to be preferred. Symington‖ and to a certain extent Féré¶ arrived at their conclusions by sections through the frozen head. Hefftler endeavoured by an application of Lucae's geometrical process to sketch within a single original outline the various parts exposed during the successive steps in the dissection which is required to expose the brain. Fraser** has recently, in an ingenious manner, employed composite photography to attain a somewhat similar end.

In my endeavours to arrive at accurate results regarding the topography of the various cerebral sulci, I have employed several different methods; but throughout the entire investigation I have recognised that the most reliable measurements could only be obtained from the brain while still within the cavity of the cranium. It would be impossible to indicate with any degree of detail the different methods which I have pursued. In the case of fœtal brains, I removed in the first instance the parietal bone and subjacent dura mater on one side, and then mapped out the area on the surface of the cerebrum covered by this bone by inserting

* "Sur le siége de la faculté du langage articulé," Bull. de la Soc. Anatomique, 1861.

† Die Grosshirnwindungen des Menschen, &c. Munich, 1868.

‡ "On the Relations of the Human Cerebrum to the Outer Surface of the Skull and Head," Jour. Anat. and Phys., 1873.

§ "Izviliny golovnavo mozga ou tchelovicka i otnochenia ich k'svodou tcherepa," Dissertation Inaugurale Chirurgicale a l'Acad. Med. Chir. de St. Petersbourg, 1873.

‖ Topographical Anatomy of the Child. Edinburgh, 1887.

¶ "Sur le développement du cerveau considéré dans ses rapport avec la crane," Revue d'Anthrop., 1879 (and several other important Papers).

** Guide to the Operations on the Head, Churchill. London, 1890.

small pins at short intervals from each other. Féré adopted very much the same plan, but as he only sought to determine the absolute distance of the fissure of Rolando, the parieto-occipital fissure, and the Sylvian fissure from the coronal, lambdoid, and squamous sutures, he made his measurements on the fresh head. When the pins were accurately adjusted, I transferred the entire head into a chloride of zinc bath, and afterwards into alcohol. This plan gave admirable results. Of course the cerebrum was considerably reduced in bulk, but the shrinkage was uniform; and as it was relative and not absolute results I desired, the diminution in bulk was not a matter of any consequence.

In the case of children and adults, models were made of the head with the brain exposed *in situ*. In the preparation of these models the following methods were employed:—The head and the entire length of the neck were removed from the trunk, and injection pipes introduced into the internal carotid arteries. Twice daily the head was injected with the following fluid:—One part spirit (sixty over proof), and two parts Müller's fluid. To each injection four drachms of glycerine were added. This treatment was continued for a fortnight. The head was then washed in water, the scalp removed from the right side, and the preparation fixed in a vice. The whole of the right side of the cranial wall, with the exception of narrow bars corresponding to the sutural lines, was next removed by means of a sharp chisel and a mallet. The utmost care was taken to preserve the dura mater entire, because it was found that so long as this was intact the injections could be continued, and the brain kept from shrinking. But now the greatest caution was necessary in making the injections, because any excessive pressure was sure to make the brain bulge and spoil the preparation. In the preparation of small brains, as in the case of children and apes, I found latterly that it was better to dispense with the Müller's fluid and use weak spirit alone.

When the brain was sufficiently hard it was necessary to wash out the spirit and Müller's fluid by two or three injections of water, or in some cases a 10 per cent. solution of hydrate of chloral, because it was always found that the hardening fluid prevented the plaster of Paris setting properly on the surface of the brain.

After this treatment the brain, on removal of the membranes, provided

it were kept moist, would retain its full size, and not undergo the least shrinkage for at least twenty-four hours. A sixth of this time, and indeed latterly very much less, was quite sufficient for obtaining a satisfactory mould.

At first I took the mould entirely in plaster of Paris, but this was a lengthy process, and necessitated no less than thirteen or fifteen separate pieces. Before I had gone far (after my sixth model had been completed) I hit upon a much more satisfactory and expeditious plan. I made a combination mould of plaster of Paris and gelatine. The surface impression of the brain I took in four or five plaster pieces, and the remainder of the head I took in gelatine. This method yielded excellent results.

Twenty-two models of the human head, one of the orang, one of the chimpanzee, one of the baboon, two of the Macacque, and one of Cebus were prepared. The majority of these are figured in Plates V. to VIII.

But this was a very laborious undertaking, and could only be carried out on a comparatively small number of individuals. It was therefore found necessary to supplement the facts obtained in this way by others acquired by a less tedious process.

The following method afforded excellent results. One-half of the cranial vault was removed by a sagittal cut a little to the one side of the mesial plane, and a horizontal cut a short distance below the highest point of the squamous suture. The cerebral hemisphere of that side was then removed, and the head placed so that it rested upon the opposite side. The falx cerebri was next detached, and the mesial surface of the hemisphere still in position exposed. Upon this it was easy to recognize the parieto-occipital fissure, and the upper end of the fissure of Rolando. The latter could be determined from its position in relation to the upturned extremity of the calloso-marginal sulcus. The point at which the fissure of Rolando turns over the upper margin of the hemisphere being determined, a peg was here driven through the cranial wall from within outwards. Another peg was driven in a similar manner into the skull, opposite the point where the parieto-occipital fissure reached the upper border of the hemisphere. The cerebral hemisphere was then extracted without injury to the tentorium or the cerebellum. On looking closely at the dura mater as it clothed the deep surface of the lateral wall of the

cranium a ridge indicating the position and direction of the posterior horizontal limb of the Sylvian fissure could usually be detected. The point of the knife was drawn along this line so as to incise the dura mater and make a distinct mark.

The falx cerebri was now stitched tightly back in its place so as to render the tentorium tense and a cast of the interior of the cranium taken. The pegs which had been introduced opposite the upper ends of the fissure of Rolando, and parieto-occipital fissures projected slightly into the interior of the cranium, and marked on the cast the position of each of these fissures. Before drawing the cast the sutural lines were mapped out on its surface by driving an awl through the skull at short intervals.

On such a cast accurate information was obtained—(1) upon the position of the upper ends of the parieto-occipital and Rolandic fissures with reference to each other, to the fore and hinder ends of the cerebrum, and to the coronal and lambdoid sutures; (2) upon the position and direction of the Sylvian fissure and its relation to the squamous suture.

But it was impossible to note the sutural relations of the fissures in every instance. Time would not allow of this. A large number of measurements have therefore been made upon brains removed from the cranial cavity. In every case, however, they have in the first instance either been carefully hardened *in situ* or plunged at once into a chloride of zinc bath, and thus fixed in their natural shape.

Measurements.—In determining the length of the cerebrum, either along its upper border or its lateral surface, it is absolutely essential that the points between which the measurements are taken should be rigidly adhered to throughout, and it is by no means an easy matter to select points which are in every respect satisfactory. Eberstaller measures from the inner angle of the trigonum olfactorium to the point where the occipital lobe first touches the tentorium. There cannot be a doubt that this is a good method, and one which is calculated to give accurate results; but both of his points are on the under surface of the brain, and consequently it is impossible to adopt his plan when the brain is being measured *in situ.* I have been forced therefore to select different points from which to make my measurements. In front I fixed upon a point on the upper or mesial

border which corresponds to the level of the outer part of the superciliary margin of the frontal lobe. This border is very far from being horizontal. Its outer part is on a much higher level than the inner part. As it is traced inwards it is seen to take a sudden curve downwards towards the cribriform plate of the ethmoid bone, where it merges with the mesial border. A line drawn horizontally inwards from the high outer part of the superciliary border of the frontal lobe cuts the mesial border of the cerebrum at the point which I arbitrarily selected as the anterior end of the cerebrum. It lies, as a rule, just below the most projecting part. Behind I took the most prominent part of the occipital pole.

The first of these points may be distinguished as the *frontal point*, and the latter as the *occipital point.* Further, the distance between these two points measured along the upper border of the hemisphere may be termed the *mesial length.*

Illustrations.—With very few exceptions, the figures in the eight Plates which accompany this Memoir were drawn upon the stone from photographs of the specimens which are depicted. Mr. Rubert Boyce, M.B., furnished me with photographs of the early brains preserved in the Museum of University College, London, whilst my Assistant, Mr. F. Dixon, B.A., and Dr. L. Macrory, executed the photographs from which the majority of the other figures have been taken. I am greatly indebted to these gentlemen for the valuable assistance they have given me.

In the course of my work I found the apparatus for tracing orthogonal projections of the skull devised by Dr. W. Matthews* of the United States Army of very great service. A number of outline tracings obtained in this way are reproduced in the text in Chapters IV. and V. But in addition to affording a means of obtaining accurate illustrations, the apparatus proved most useful in enabling me to reduce the sulci on the surface of cerebral hemispheres under consideration into a series of trustworthy charts, which threw a considerable amount of light upon the fissural arrangement in each case, and rendered the comparative study of the sulci easier. By it also the various angles (*e. g.* Rolandic angle, intraparietal angle, &c. &c.) can be determined with great accuracy.

* For a description of this apparatus, *vide* "Journal of Anatomy and Physiology," vol. xxi., p. 43.

CHAPTER I.

THE COMPLETE FISSURES OF THE HUMAN CEREBRUM.

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I. **General Statement.**—The complete fissures of the cerebral mantle (the "Totalfalten" of His) appear at an early period in the development of the hemispheres. They are distinguished by the fact that they are the result of a series of deep infoldings of the thin cerebral wall. On the surface of the fore-brain they present a sharply-cut linear appearance. The walls of the different folds are, as a rule, closely applied to each other; and they constitute shelf-like projections into the cavity of the primitive lateral ventricle.

The study of these infoldings is a matter of extreme difficulty, because by far the greater number of them have only a temporary existence. As cerebral growth advances they are obliterated, and the hemisphere surface again becomes smooth. Several, however, occupy positions which later on are occupied by permanent furrows. It is not surprising, then, that very different opinions should be expressed regarding the fate of these primitive infoldings which present this relation to the permanent furrows. More especially do we find the calcarine and parieto-occipital fissures the subject of contending views.

Amongst the "Totalfalten" His* includes the fossa Sylvii, but Mihalkovics† rightly denies it a place in this category. The majority of anatomists, however, agree with the former observer. Thus Hertwig, in the third edition of his treatise on Embryology,‡ distinctly gives expression to that view.

The projection into the hemisphere cavity which corresponds to the fossa Sylvii (viz. the corpus striatum) is not formed by an infolding of the mantle wall, but as an elevation which rises on the floor of the prosencephalon. The surface area corresponding to this internal projection does not keep pace with the mantle as the latter grows around it, and in consequence the Sylvian depression makes its appearance. The development of this fissure then is peculiar, and altogether different from that of the "Totalfalten" of His.

Under ordinary circumstances, and under normal conditions, none of the complete fissures which appear on the outer face of the embryonic hemisphere are retained as permanent sulci. Later on we shall have occasion to mention two which apparently persist in the ape. The corresponding fissures in man, however, are of a transitory nature.

On the inner or mesial face of the hemisphere the conditions of growth are different. These are more favourable to the appearance of such infoldings, and also more favourable to their retention. It is here, therefore, that we find the complete fissures which are preserved in the adult brain. These are:—(1) the choroid fissure; (2) a portion of the arcuate fissure; (3) and under certain conditions the parieto-occipital, with the fore-part of the calcarine fissure.

II. **Choroid and Arcuate Fissures.**—In his recent work upon the development of the human fore-brain, His gives an excellent account of the early development of these fissures. They appear at a very early period on the inner surface of the hemisphere. His figures the cerebrum

* Unsere Körperform, Neunter Brief, p. 116.

† Entwicklungsgeschichte des Gehirns, 1877.

‡ Traité d'Embryologie ou Histoire du Developpement de l'Homme et des Vertébrés, par Oscar Hertwig (traduit sur la troisième édition allemande par Charles Julin, Paris, 1891), p. 395.

of an embryo which has barely reached the fifth week in which they are present.

The *choroid fissure* occupies the lowest limit of the mesial wall, and pursues a semilunar course. In front it reaches forward to the foramen of Monro, whilst behind it curves downward, and extends towards the extremity of the temporal lobe. It is formed by a deep infolding of the mantle wall; and the fissure formed between the two layers of this fold contains in the first instance no blood-vessels, and no extension from the connective tissue which occupies the primitive longitudinal fissure and represents the early condition of the falx major. As His remarks: "The formation of the fold cannot therefore, as frequently happens, be explained as a sinking in of the hemisphere wall through the ingrowing of blood-vessels. The fold arises through an independent surface extension of the epithelial layer." Later on it becomes occupied by the choroid plexus. The two layers which form the fold remain epithelial, and do not develope into nervous tissue.

The *fissura arcuata* (*Bogenfurche* of Arnold, or *Ammonsfurche* of Mihalkovics) makes its appearance on the mesial face of the hemisphere at a higher level than the choroid fissure. Like the latter it pursues a curved course, and between the two fissures a semicircular portion of the inner surface of the hemisphere is marked off, which receives the name of arcus marginalis (*Randbogen* of Schmidt). In front the fissura arcuata extends into the frontal region, whilst behind it is carried round towards the extremity of the temporal lobe.

His has recently shown that the fissura arcuata in the early stages of its development is composed of two portions which he terms the "*vordere Bogenfurche*," and the "*hintere Bogenfurche*." The former begins as a deep furrow on the mesial face of the olfactory lobe, and takes an upward and backward course. Becoming gradually shallower it ends above the forepart of the choroid fissure. The hinder portion of the fissura arcuata is

* Die Formentwickelung des menschlichen Vorderhirns vom ende des ersten bis zum Beginn des dritten Monats—Des xv. Bandes der Abhandlungen der mathematisch-physischen Classe der Königl. Sächsischen Gesellschaft der Wissenschaften. No. viii. Leipzig, 1889, pp. 694 and 712.

the part which more particularly corresponds with the *Ammonsfurche* of Mihalkovics. It appears about the same time as the fore-part, but in the first instance the two portions remain distinct and separate. Ultimately, however, they meet at the hinder end of the choroid fissure to form the continuous furrow which we have described.

The arcuate and choroid folds can best be studied by removing the roof of the hemisphere. The manner in which they project into the ventricular cavity so as to overlie the corpus striatum can then be seen.

As we have already mentioned, the term arcus marginalis is applied to the portion of the mesial face of the hemisphere which lies between the choroid and arcuate fissures. This is an important strip of mantle surface. In connexion with it the fornix, corpus callosum, and gyrus dentatus are formed.

The facts stated above regarding the fissura arcuata are well known, and have been carefully and faithfully described by several embryologists. It would appear, however, that the fissure does not always present the simple condition which we have noted. His,* who maintains that the inner face of the cerebrum is at no time smooth and devoid of furrows, figures the fissura arcuata in a ten weeks' fœtus; and he represents its hinder end rising upon the mesial face of the hemisphere until it ultimately reaches the upper border; turning round this it is continued downward on the outer surface of the back-part of the cerebral mantle. Mihalkovics,† commenting upon this, denies that the fissura arcuata ever extends upward to the free border of the hemisphere. I entirely agree with the latter observer. In none of the specimens in my possession is the condition described by His present.

The hind-part of the primitive fissura arcuata, which bounds the arcus marginalis, is retained in the adult brain as the hippocampal fissure, and gives rise to the elevation in the floor of the descending horn of the lateral ventricle which is known as the hippocampus major.

The fore-part of the fissura arcuata is generally believed to form in the

* His, Unsere Körperform, Leipzig, 1875, p. 113, fig. 112.

† Mihalkovics, Entwicklungsgeschichte des Gehirns, Leipzig, 1877, p. 158.

advanced brain the callosal fissure. Certain observers speak very decidedly upon this point. Schwalbe* remarks: "The 'Bogenfurche' in its upper part becomes the upper boundary of the corpus callosum." Schmidt† gives expression to a similar view but considers that a portion of the fore-part of the fissure "gradually disappears as the hemisphere wall increases in thickness." Mihalkovics‡ states that, "during the formation of the corpus callosum, it becomes shallower; and as the upper surface of the corpus callosum extends at a later period up to this furrow, the latter is retained in that deep incision which lies between the corpus callosum and the gyrus fornicatus." The beautiful drawings which accompany Mihalkovics' monograph can hardly be said to bear out this statement. In figs. 24 and 25 the shallow anterior end of the arcuate fissure is seen ending at a higher level than the corpus callosum, whilst there is not a trace of the "vordere Bogenfurche" represented. Hertwig employs equally decided language in regard to this point. He says: "The callosal fissure . . . . constitutes then the anterior part of the arcuate fissure, whilst the posterior part is termed later the great hippocampal fissure."

A study of the specimens which I have collected has forced me to adopt a different view in regard to the fate of the fore-part of the fissura arcuata. I have not been able to satisfy myself that any part of it is retained as the callosal sulcus. I believe that it is transitory, and that it is gradually obliterated during the time that the corpus callosum assumes shape. A brain which is figured in Plate I (fig. 12) first led me to doubt the generally accepted view in regard to this question. It was obtained from a fœtus, which had apparently reached a stage of development corresponding to the first half of the fourth month. There is not a trace of the corpus callosum, but the fornix is fully formed in connexion with the lower edge of the arcus marginalis, although the two sides have not as yet adhered to form the central body part. The fissura arcuata is in three separate portions—a hinder part corresponding in position with the future

* Lehrbuch der Neurologie, p. 256.

† "Beiträge zur Entwicklungsgeschichte des Gehirns," Zeitsch. f. Wiss. Zool., 1862, Bd. xii., pp. 54, 55.

‡ Entwicklungsgeschichte des Gehirns, p. 148, vide pl. III., figs. 24, 25.

hippocampal fissure (*h*) and two shorter anterior portions which are placed upon the fore-part of the mesial surface of the hemisphere. Of the latter the one is a straight fissure which takes an oblique course downwards and forwards toward the lower and fore-part of the frontal lobe (*e*); the other lies immediately behind this, and on a higher level (*f. a.*). The same condition was present in both hemispheres. Not only then has the front part of the fissura arcuata liberated itself from the hinder hippocampal part, but it has broken up into two parts, a sure sign that it is in course of obliteration. On removing the roof of the left cerebral vesicle the infolding of the hemisphere wall, corresponding to the posterior of the two anterior portions, is seen to project horizontally outward like a shelf across the greater part of the width of the cerebral vesicle (Pl. I., fig. 13, *f. a.*). In this situation it lies over the anterior part of the corpus striatum. The depth of this fold may be appreciated by examining fig. 1, which represents a transverse section through the fold as seen under a low power.

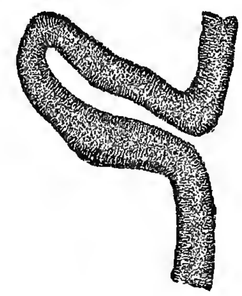


Fig. 1.

Section through the fore-part of the fissura arcuata. The hemisphere from which this specimen was obtained is figured in Pl. I., fig. 13.

The detachment of the anterior part of the fissura arcuata in this specimen and the similarity which it presents to temporary infoldings in the course of their obliteration is highly suggestive, and favours the view that the posterior hippocampal part of the arcuate fissure alone is retained; or in other words, that the front part is wiped out, and that the callosal sulcus in the fully formed brain is a new fissure which is called into existence at the time when the callosal fibres cross from one hemisphere to the other. In this opinion I am confirmed by the examination of brains somewhat more advanced, and in which the corpus callosum is seen in different stages of formation. It would appear that in the process of disappearance the arcuate fissure does not necessarily break up into separate pieces as exhibited in fig. 12, Pl. I. It may become obliterated by a gradual shallowing which travels forward from the hippocampal part. The last part to disappear in such a case is the foremost portion on the mesial face of the

frontal lobe. In all cases the shallow furrow lies at some little distance above the level of the corpus callosum. In illustration of this, figs. 15 and 16, Pl. I., and figs. 3, 4, 5 and 6, in Pl. III., may be examined. In fig. 16, Pl. I., and in fig. 6 in Pl. III., the commencing true callosal fissure may be noted at a lower level than the arcuate fissure. In all the figures the anterior deep part of the fissure still persists as a very distinct and deep fold. In the course of time it also disappears.

The calcarine and parieto-occipital fissures would naturally fall to be considered at this stage, but their origin is so closely connected with the appearance of the transitory fissures, that it is more convenient to defer their examination until the latter have been dealt with.

III. **The Transitory Fissures.**—(*Vorübergehenden Rinnen*, of Schwalbe; *Temporären Furchen*, of Ecker and His; *Vergänglichen Furchen*, of Mihalkovics). These are a series of fissures which appear at an early period upon the cerebral wall in consequence of deep infoldings of its thin wall. They are further distinguished by their transitory character. After existing for a period of two months or more on the mesial wall, and for about two-thirds of that time on the outer wall, they are finally completely obliterated, and the hemisphere surface becomes smooth. When we come to study the influences at work which lead to their production, we shall see that they constitute a most interesting and suggestive chapter in the developmental history of the brain.

It is to J. F. Meckel that the credit is due of having, in the first instance, recognised these transitory infoldings. In 1815 he published a Paper in which he remarks:—"Although I find the brain in the six to the seven weeks' embryo completely smooth, the very thin walls of the lateral ventricles appear to shape themselves into extremely numerous and deep convolutions and furrows from the eighth to the ninth week." He asserts that the fissures are due to deep infoldings of the hemisphere wall, and is at considerable pains to prove that the condition is not produced by the shrinkage brought about by the hardening reagent. He therefore holds that the convolutions are not accidental, but are "primitive formations and are essentially a part of the development of the brain." His account of

the manner in which these early infoldings of the hemisphere wall disappear is of some interest. We shall use his own words:—"But upon this period another supervenes in which these convolutions, as well as their outer and inner surfaces, grow into each other, so that the surface of the brain, both inside and outside, again becomes smooth." And he considers that this process of obliteration may be regarded as affording a means by which the wall of the ventricle is thickened, and also by which the white substance is increased in quantity.*

In the following year (1816) Friedrich Tiedemann† figured the transitory fissures for the first time. He failed however to recognize their temporary character, and considered that they represent the earlier conditions of the permanent sulci.

Schmidt,‡ in 1862, contributed an excellent Paper on the early development of the brain. He describes the temporary furrows and is satisfied that they are in course of time obliterated. He says:—"These folds take no share whatsoever in the formation of the real convolutions. Without doubt they are produced by the strong growth of the hemisphere in the longitudinal direction . . . a view which has also been previously expressed by others." One point of high importance he adds: viz. that, although he has failed to discover them in the embryos of the sheep, ox, and pig, he believes that he has seen faint traces of them in the brain of the early cat-embryo.

Ecker,§ His,‖ v. Kölliker,¶ Mihalkovics,** and other German authors, have likewise taken notice of the temporary furrows, although they have as a rule dealt with them briefly, and have not made a serious attempt to unravel the part which they play in the process of brain development. It is but right to mention, however, that Richter†† has given an admirable

* Deutsches Archiv f. Physiol., Halle und Berlin, Bd. i., 1815.

† Anatomie und Bildungsgeschichte des Gehirns im Fœtus des Menschen, Nürnberg, 1816.

‡ "Beiträge zur Entwicklungsgeschichte des Gehirns," Zeitsch. f. Wiss. Zool., Bd. xi.

§ "Zur Entwicklungsgeschichte der Furchen und Windungen der Grosshirnhemisphären im Fœtus des Menschen," Archiv f. Anthrop., Dritter Band, Drittes und Viertes Heft, 1869.

‖ Unsere Körperform, Leipzig, 1875.

¶ Entwicklungsgeschichte des Menschen und der höheren Thiere, 1879.

** Entwicklungsgeschichte des Gehirns, 18.

†† "Ueber die Entstehung der Grosshirnwindungen," Virchow's Archiv, Berlin, 1887.

account of the fissures in question, and has added considerably to our knowledge regarding them.

It is somewhat curious that Bischoff, writing as late as 1868, should have cast doubt upon the reality of the transitory furrows. He asserts that all previous observations in this direction are founded on an error, and that the fissures in question are produced artificially by the action of the alcohol in which the brains have been immersed. He further maintains that in specimens treated with chloride of zinc the surface of the hemisphere remains perfectly smooth up to the time of the appearance of the permanent sulci. To quote his own words:—"Die weiche und sehr wasserhaltige Beschaffenheit junger Gehirne, vor Allem die verhältnissmässig sehr grossen Hohlräume, welche die einzelnen Hirnabtheilungen umschliessen, bedingen bei dem Einbringen der Embryonen in Weingeist, welches zur Herausnahme der Gehirne unvermeidlich war, ein starkes Schrumpfen und Zusammenfallen und besonders an den Hemisphären eine Faltenbildung, welche etwas Regelmässiges zu haben scheint. Allein sie sind nur Kunstprodukt."*

Ecker disposes of this objection by the statement that he has observed the transitory furrows in the brain of a third-month embryo which was examined in the fresh state. I can verify this statement, as I have frequently seen the fissures under similar conditions, and moreover I have chiefly studied them in brains prepared by the chloride of zinc method. At the same time I fully agree with both Ecker and His in considering that some care must be exercised in distinguishing between true and artificial folds in the thin wall of the cerebral wall. The latter author, in his recent work upon the forebrain, very properly remarks:—"In human material one meets with the special difficulty that the thin-walled hemisphere vesicle frequently, through external accidents, becomes folded (through pressure upon the head in birth or in the preparation of the embryo, or through shrinkage in consequence of defective preservation), and that the accidental folds thus produced are combined with the natural folds. With some circumspection in the choice of material one can

* Die Grosshirnwindungen des Menschen, &c. &c., Abh. d. 11. Cl. d. k. bayer. Akad. d. Wiss. Bd. x., Abth. 11., p. 446.

distinguish the one from the other, and the constancy and uniformity of the natural folds serve as a sure means of distinction."* After some experience there is little danger of confounding an artificial with a natural enfolding of the hemisphere wall.

In Italy Giacomini,† Romiti,‡ and Mingazzini § have paid some attention to the temporary fissures, but in this country little or no notice has been taken of them. It is true that Callendar,|| in his "Lectures upon the formation and early growth of the Brain of Man," has referred to them, but his systematic neglect of the work done by others in the same field greatly diminishes the value of his observations.

The material which I have had at my disposal for observing the characters and tracing the history of the temporary fissures has been fairly abundant. In all I have had fourteen hemispheres which come within the limits of the prescribed period. The following is a list of these:—

Number of Hemispheres.	Longitudinal Diameter.	Probable Period of Development.
2	15 mm.	Latter part of the second month.
2	19 mm.	Beginning of the third month.
4	25 mm.	Between the third and fourth months.
2	27 mm.	First week of the fourth month.
2	28 mm.	First week of the fourth month.
2	33 mm.	Three ~~Four~~ and a-half months.

* Die Formentwickelung des menschl. Vorderhirns, &c., Des xv. Bandes der Abhandlungen der Math. Phys. Cl. der Königl. Sächsischen Gesellschaft der Wiss. No. VIII., p. 694.

† Guida allo studio delle circonvoluzioni cerebrali dell' uomo. Torino, 1814.

‡ "Sull' ordine di successione, con il quale appaiono le scissure cerebrali," Processo Verbale della Soc. Toscana di Sci. Nat., 1882.

§ "Ueber die Entwicklung der Furchen und Windungen des menschlichen Gehirns." Untersuchungen zur Naturlehre des Menschen und der Thiere, herausgegeben von Jac. Moleschott, xiii. Band, 6 Heft.

|| British Medical Journal, June 6, 1874.

With one or two exceptions where it was necessary to prepare the hemispheres for microscopic examination, all my specimens have been preserved by the same method. A mesial incision having been carefully made through the cranial capsule, and the dura mater cut on each side, the whole embryo was immersed in a saturated solution of chloride of zinc. In this it was allowed to float for a period of thirty-six hours, and then it was transferred to methylated spirit. The brain was thus hardened *in situ*. When dealing with fresh embryos in which the head had not been previously subjected to pressure or otherwise damaged, I have never found this method to result in the production of artificial infoldings of the cerebral wall. When the brain substance had attained a proper consistence, the cerebrum was exposed by cutting through the cranial capsule and dura mater along the sutural lines with a pair of scissors. In the few cases in which it was desirable to prepare the brain for microscopic examination, I employed Müller's fluid.

But in addition to the specimens which have come into my own possession, I have been allowed, in the most generous manner, to handle, describe, and photograph four very characteristic embryonic brains which are preserved in the museum of University College of London. These range from the beginning of the third month up to the first week of the fourth month or thereabouts. Further, Professor Victor Horsley has been so kind as to furnish me with a beautiful series of photographs of the fœtal brain preparations which are displayed in the museum of the University of Oxford. One of these, figured in Plate i. (figs. 9 and 10), which has probably reached the fourth month of development, is especially interesting. The figures which are given by Schmidt, v. Kölliker, and Richter I have also found useful, although those which we commonly see in our text books, and which have been taken from Ecker and Mihalkovics, cannot be regarded as giving a proper idea of the transitory furrows as they exist during the period of maximum development.

Duration of the Transitory Fissures.—The mesial wall of the hemisphere is considerably thinner than the outer wall; and it is partly in consequence of this that the transitory fissural infoldings first make their appearance upon it. But we have the most conflicting statements regarding

the actual period at which they first begin to be formed, and also regarding the time at which they vanish. These statements will best be contrasted if I place them in tabular form :—

Duration of Transitory Furrows.

Authority.	Period of Appearance.	Period of Obliteration.
Meckel.	Eighth to the ninth week.	—
Schmidt.	Middle of the third month.	End of the fourth month.
Ecker.	Third to the fourth month.	Commencement of the fifth month.
v. Kölliker.*	Third month.	Fifth month.
Mihalkovics.	Middle of the third month.	Commencement of the fourth month.
Romiti.	Tenth week.	End of the fourth month.

We may remark here that the description given by Schmidt hardly agrees with his figures, because the transitory fissures are indicated by him on the mesial surface of a cerebrum taken from an embryo at the eighth week, which bears out the original observation of Meckel.

The difference of opinion which is shown in the above table results, no doubt, very largely from variations in the duration of these fissures, but it is likely that it is also in a great measure due to the almost insuperable difficulty of giving to an embryo its proper age. The same embryo in the hands of different observers would, I am satisfied, be reckoned at very different periods of development. As I have stated, the embryos which I have specially studied with the view of obtaining a knowledge of the transitory fissures ranged from the beginning of the third month to about the end of the fourth month. In all of these the transitory fissures were visible. Clearly Mihalkovics is wrong in limiting the time of their existence to one fortnight. It appears equally certain that they may begin on the mesial face of the hemisphere as early as the eighth week. Meckel

* Entwicklungsgeschichte des Menschen und der höheren Thiere, 1879.

has told us so, and Schmidt has figured them at this stage; but they do not attain, even on this aspect of the hemisphere, a high degree of development until the ninth or the tenth week. Again, we must not forget that if we are to regard the "vordere Bogenfurche" of His as a transitory fissure, we must consider that the process actually begins on the inner surface of the hemisphere as early as the fifth week. As we shall see further on, however, this fissure hardly belongs to the same series as the others, seeing that it presents an altogether different direction.

On the outer surface of the hemisphere the formation of the transitory fissures is delayed. It is doubtful if they ever show on this aspect before the tenth week. In most cases they attain their maximum degree of development between the third and fourth months, and this holds good for both surfaces of the hemisphere.

A certain amount of latitude must also be allowed in reckoning their time of disappearance; but as a rule it will be found that they become obliterated between the periods at which the fornix and corpus callosum become developed; in other words, somewhere towards the end of the fourth or the beginning of the fifth month. From this general statement, however, we must make an exception in favour of two fissures which appear on the outer aspect of the occipital lobe, and whose history I purpose discussing at some length further on.

Transitory Fissures on the Medial Wall of the Hemisphere.—As a general rule, the transitory fissures on the mesial wall of the hemisphere are very definite in their relations, although they vary greatly in number. (Pl. i., figs. 5 and 12; Pl. iii., figs. 1 to 6). They consist of a series of furrows which radiate in a stellate manner from the fissura arcuata (*Bogenfurche*) towards the free border of the hemisphere. At first they appear as a number of notches or indentations in the upper boundary of the fissura arcuata. These are shallow and broad at the base, and they give to the medial cerebral wall a wrinkled or crumpled appearance. At this stage they might very readily be mistaken for depressions brought about by the shrinkage of a hardening reagent. After a while they deepen and lengthen out, and they may extend as a continuous series all the way round from the frontal pole in front to the extremity of the temporal pole below. The

majority of the radial transitory fissures on the medial face of the hemisphere do not reach so far as the border of the hemisphere, but two at the occipital or postero-superior pole, very constant in position and longer than the others, almost invariably do so (*p. o.* and *c.*); and occasionally in the frontal region and at the end of the temporal lobe one or more may also show a similar extension.

In addition to the radial furrows issuing from the fissura arcuata we frequently find others parallel to them, but close to the free border of the hemisphere, and not connected with the arcuate fissure. These may be independent infoldings, or they may merely represent the upper extremities of fissures on the outer surface of the cerebrum, turning over the upper border of the hemisphere.

As we have stated the number of radiating temporary fissures on the medial aspect of the hemisphere varies very greatly. In one cerebral hemisphere Richter counted nine, and in another only five. The number is usually the same, or approximately so, on the two hemispheres of the same brain, and the usual number seems to be eight. Eighteen hemispheres all between the beginning of the third and the end of the fourth months yielded the following results in this respect:—

In	9	there were	8	fissures.
,,	3	,,	6	,,
,,	2	,,	11	,,
,,	1	,,	4	,,
,,	1	,,	5	,,
,,	1	,,	7	,,
,,	1	,,	9	,,

No doubt the difference in the number of fissures on the medial surface is partly due to the different periods of development at which the brains were examined, but I do not believe that this is the only factor present in determining the variations. The influence at work in calling the infoldings of the cerebral wall into existence appears to be a purely mechanical one, viz. a restraint placed upon the longitudinal growth of the hemisphere; and this being the case it is easy to understand how the number and depth

of the fissures will vary with the degree and kind of restraint which is applied.

Primitive Cuneate Subdivisions of the Medial Hemisphere Wall.—By the presence of the stellate fissures, when they are developed in a marked form, the medial surface of the hemisphere outside the fissura arcuata is subdivided into a number of wedge-shaped or cuneate portions. That portion which intervenes between the two long fissures, which we have mentioned as being always present on the occipital part of the hemisphere, is retained as the cuneus of the adult brain. The other portions in front of this region, and also those below it, again run into each other when their bounding fissures are obliterated, and they then form the smooth tracts out of which the gryus fornicatus, calloso-marginal convolution, præcuneus, and the convolutions on the under surface of the occipital and temporal lobes are ultimately formed. The primitive fissures which bound the cuneus are the precursors of the calcarine and parieto-occipital fissures.

Obliteration of the Transitory Fissures.—To study in all its details the manner in which the transitory fissures disappear and vanish from the mesial face of the hemisphere, so as not to leave a single trace of their former existence either on the inside or the outside of the cerebral wall, would require a very large number of specimens, and these very varied as to their term of development, because it is clear that the process differs considerably in different cases. Still in the material at my disposal a number of interesting points can be determined, and the general details can be ascertained. As the wall of the cerebral vesicle thickens, and the hemisphere elongates, one or more of the stellate fissures become detached from the fissura arcuta. They then appear as short isolated fissures (Pl. i., fig. 12; Pl. iii., figs. 3, 4, 5, and 6). These continue to decrease in length until they appear as little more than mere points or shallow dimples, corresponding with which small rounded elevations on the inner aspect of the wall of the ventricular cavity are seen. Finally these disappear also, and both surfaces of the wall become smooth and even. In fig. 18, Pl. i. (*e. c.*), the rounded intra-ventricular elevation corresponding to a reduced and rapidly vanishing transitory fissure, the remains of an inward fold, is seen on each side. It is true that this is the internal

expression of a fissure on the outer surface of the hemisphere, but the process is virtually the same with all the transitory furrows, whether on the mesial or the lateral surface of the cerebrum.

But as we have already mentioned, the fisura arcuata itself breaks up (Pl. I., fig. 12). In all cases the posterior hippocampal portion is preserved *in situ,* and, in connexion with it, the precursors of the calcarine and parieto-occipital fissures may remain attached. The obliteration of the fore-part of the fissura arcuata with the radial fissures in connexion with it, as we have already observed, may be effected in different ways. The manner in which the stellate furrows free themselves from the arcuate fissure previous to their complete disappearance is well seen in figs. 3, 4, 5, and 6, Pl. III. The persistence of the foremost part of the arcuate fissure on the inner face of the frontal lobe is very remarkable. In figs. 15 and 16, Pl. I., which represent two hemispheres from an embryo in the early part of the fifth month of development, it is still apparent, although all the radial furrows have become completely obliterated.

Transitory Fissures on the Outer Surface of the Hemisphere.—The transitory fissures are not, as a rule, disposed so uniformly on the outer face of the hemisphere as they are upon the medial face. (Pl. I., figs. 1 to 4, and 6 to 11; also Pl. II., figs. 1 to 7.) Starting from the free border of the hemisphere, they run in a convergent manner towards the Sylvian region, or, in other words, towards the hilum of the bean-shaped cerebrum; but as a general rule they fall short of this. In well-marked cases they are present all the way round the mantle border from the frontal pole in front to the temporo-sphenoidal pole below. At some particular part of the circumference it is usual to see them more concentrated or more closely placed and more numerous than elsewhere. In certain cases this may occur in the frontal region (Pl. I., figs. 4, 7, and 9); in other instances it is in the parietal region that the crowding together takes place (Pl. I., figs. 2 and 3).

But the fissures have not always the simple and uniform arrangement described above. With these, others are usually associated. Thus, it is by no means uncommon to see a fissure occupying a position and possessing a direction similar to that of the adult Sylvian fissure (Pl. I., figs. 6, 7, 8, and 9*b*). This was present in eight instances, and it was no mere super-

ficial furrow, but a deep cleft, which separated the upper and front part of the cerebrum from the lower and back portion almost as effectually as the clefts of the lung separate its various lobes. Altogether this is a most striking infolding. It is seen in great perfection in one of the specimens displayed in the museum of University College, London (Pl. I., figs. 6, 7, and 8). All the brains in which it occurred I reckoned to be about the same period of development, viz. from the thirteenth to the fourteenth week. In brains younger than this (Pl. I., fig. 1), or older (Pl. I., figs. 4 and 11), there is not a trace of it. At the same time, I am not prepared to say that this remarkable fissure is always present. It is clear, however, that there is a marked tendency towards the formation of such a fissure under certain conditions of growth-restraint, and that these conditions appear to be frequently present at the period indicated. In those brains in which this infolding is present there seems to be some delay in the formation of the Sylvian fossa. As the fossa assumes shape the fissure retreats before it, although in two cases I have seen it cutting through the upper boundary of the fossa, and encroaching to a very slight degree within its limits.

In one hemisphere a second deep cleft was present, below and parallel to that just described (Pl. I., fig. 8). It therefore occupied the ground of the future parallel sulcus of the fully developed brain. It has nothing whatever to do with the development of the permanent sulcus.

Again, it is by no means unusual to observe short isolated fissures removed a short distance from the upper free border of the hemisphere. In many cases, these are doubtless fissures in process of obliteration. They are chiefly noticed in specimens between the third and fourth month.

In certain hemispheres the fissure on the mesial face, which we have named, provisionally, the precursor of the calcarine fissure, is carried horizontally round the occipital pole, cutting it deeply, and appearing on the outer surface in the form of a fissure, which we may term the *external calcarine* (Pl. I., fig. 10, *e. c.*). This fissure has a most interesting history, which I purpose tracing at a later part of this chapter. In the meantime, I may merely call attention to the fact that this external calcarine fissure was present in the great majority of the hemispheres examined, although

it was not, in every case, continued round the occipital pole into the precursor of the calcarine fissure on the medial face of the cerebrum (Pl. I., fig. 12, *e. c.*).

In Pl. I., fig. 1, the left hemisphere of an embryo at about the eleventh week is represented. Two short fissures—one in front and the other behind—are alone present on the outer surface of the cerebrum. Between these, however, the cerebral mantle is faintly streaked by a series of grooves, which present very much the direction of the transitory fissures when fully developed. Most likely these markings indicate the initial stages in the formation of the fissures. When fully formed, a deep infolding is the result. This figure may be compared with fig. 1, Pl. III. In this a brain about the same stage is depicted, and yet there are well-marked fissures present. This shows the variability in the time at which these infoldings occur.

Figure 2 shows a transverse microscopical section through the middle of the fissure indicated in the frontal region of the brain depicted in Pl. I.,

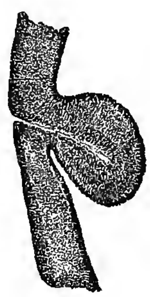


Fig. 2.

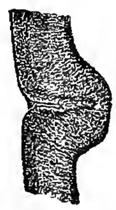


Fig. 3.

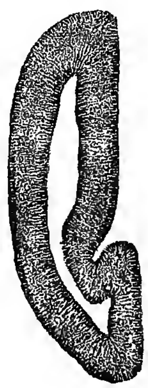


Fig. 4.

Fig. 2.—Transverse section through the middle of the fissure lettered "*f*" in Pl. I., fig. 11.
Fig. 3.—Transverse section through the extremity of the same fissure.
Fig. 4.—Transverse section through the fore-part of the central vesicle figured in Pl. I., fig. 13. On inner side, note shallow fore-part of the fissura arcuata.

fig. 13 (*f.*). The lips of the furrow are closely applied to each other at the surface, and it is this that gives to such fissures their sharply-cut linear appearance; but, towards the bottom of the sulcus, the walls of the fold are separated to a small extent, and a slight recess is formed between them.

Schmidt has stated that, at the places where the bending-in of the cerebral wall takes place, the wall of the hemisphere is thinner than elsewhere. This is well seen in fig. 2, although on the one side of the fissure it is better marked than on the other. At the same time it must be noted that this condition is not universally present. In the shallow parts of a fissure, or where a fissure is shallow throughout, it is the bottom of the fold that becomes thinned (figs. 3, and 4). When a continuous series of sections is made through the entire length of one of the transitory fissures the central part is seen to be very deep (fig. 2), while at its two extremities it is shallow, and the bottom gradually rises to the surface (fig. 3). The folds, therefore, as seen from the ventricular aspect, present a semilunar form (Pl. I., fig. 13, *f.*).

A study of the various specimens would seem to indicate that the process of obliteration consists in a shortening of the fissure from both extremities towards the centre. More and more of the bottom of the furrow rises to the surface, until at last the deep central part alone remains in the form of a round knob-like elevation on the ventricular aspect of the wall (Pl. I., fig. 18, *e. c.*). Ultimately this disappears also. During this process the fissures retreat from the hemisphere margin, and in several of the figures which are given in Plates I. and II., one or more of these may be observed. But it is necessary to mention here what we shall have to insist upon more fully hereafter, viz. that this obliteration does not seem to depend solely upon a process of unfolding, but that a certain amount of absorption of the fold appears also to take place.

On the outer surface, just as on the mesial surface of the hemisphere, the number of transitory fissures present varies very considerably. Fifteen hemispheres ranging from the tenth week or so up to the end of the fourth month gave the following results:—

In *none* was the surface smooth.	In 1 there were 2 fissures.
,, 4 there were 8 fissures.	,, 1 ,, 5 ,,
,, 3 ,, 3 ,,	,, 1 ,, 6 ,,
,, 2 ,, 10 ,,	,, 1 ,, 7 ,,
,, 2 ,, 4 ,,	

From the above list it will be seen that the number of temporary fissures which appear on the outer surface of the mantle is very variable; and this variability is, in all probability, due to the different conditions of growth-restraint to which the growing hemisphere is subjected in different cases. No doubt, also, it may to a certain extent be accounted for by the fact that the brains examined belong to different periods of development.

In only one brain were the fissures arranged absolutely symmetrically on the two hemispheres. This was one of the most instructive specimens of the series, and several views of it are given in Plate I. (figs. 11, 12, 13). Although not disposed in other brains in exactly the same way on the two sides, there was always noticed a general correspondence between the two hemispheres in the number and character of the fissures.

IV. **The Persistence of the Transitory Fissures under certain conditions.**—A very interesting question arises at this point:—Do circumstances ever arise under which these primitive complete fissures of the early cerebrum are retained permanently? There is good reason to believe that in some cases one or other of those we have named the precursors of the parieto-occipital and calcarine show an unbroken continuity of existence with the fissures which bear the same name in the fully-developed brain. Further, it is possible that the corresponding fissures on the outer face of the occipital lobe (external perpendicular of Bischoff and external calcarine), in rare instances, may also be preserved. Certainly they always enjoy a much more prolonged existence than the other transitory fissures, although it must also be borne in mind that one of these at least (external perpendicular) appears at a much later period. Lastly, there cannot be a doubt that in certain malformations of the brain, as, for example, absence or defective formation of the corpus callosum, this primitive and, under normal circumstances, transitory fissural system is in a measure preserved. Anton * is of opinion that the disappearance of the transitory furrows is largely due to the development of the corpus

* Zeits. für Heilkunde, Band VII. 1886. I regret very much to say that I am obliged to quote Anton's Paper second-hand. I have not been able to obtain a copy of it, and my only knowledge of the views which he enunciates are obtained from the brief passing reference which is made to it by Richter.

callosum. It is no doubt true that the obliteration is very nearly synchronous with this, but whether it is caused by it or not is altogether another matter.

Sir William Turner, in the remarkable address which he delivered to the anatomical section of the Tenth International Medical Congress in Berlin, made a very significant and suggestive remark. He said: "The radiating character of these fissures in the brains of Macropus and Halmaturus, in which it must be remembered the corpus callosum is rudimentary, is of interest in connexion with the radiated arrangement of the transitory fissures on the cranial surface of the human brain at an early period of development."* There would thus appear to be phylogenetic as well as ontogenetic evidence in favour of the view that the development of the corpus callosum is in some way connected with the disappearance of the transitory furrows. Later on I shall endeavour to prove that, however this may be, there are certainly other factors at work in bringing about this very curious phenomenon.

Recently Dr. Alexander Bruce has published in the *Proceedings of the Royal Society of Edinburgh*, vol. xv., a very able Paper upon a case of

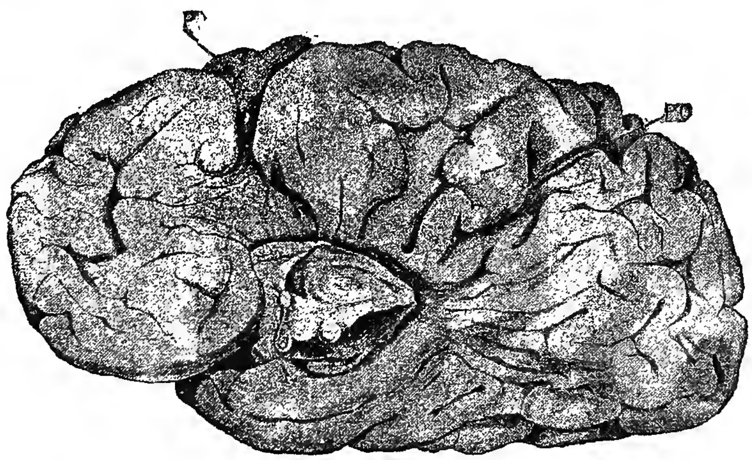


Fig. 5.—Reproduction of Dr. Bruce's figure depicting a human brain in which the corpus callosum was absent. *P.*, upper end of a fissure supposed by Dr. Bruce to be the fissure of Rolando; *PO.*, parieto-occipital fissure.

* "The Convolutions of the Brain: a Study in Comparative Anatomy," Journal of Anatomy and Physiology, vol. xxv., p. 105.

congenital absence of the corpus callosum in a human brain. The admirable drawing which he gives of the inner surface of the cerebrum I have taken the liberty of reproducing (fig. 5). There is not a trace of the calloso-marginal fissure, but, radiating from the fissura arcuata towards the free border of the hemisphere, there are a number of divergent sulci. These are undoubtedly to be regarded as the primitive, and usually transitory fissures which are always present on the mesial face of the hemisphere during the early stages of its development, and which in this case have been preserved. Equally instructive are the figures given by other authors of this face of the cerebral hemisphere in brains with no corpus callosum. Those of Eichler,* Knox,† and more especially

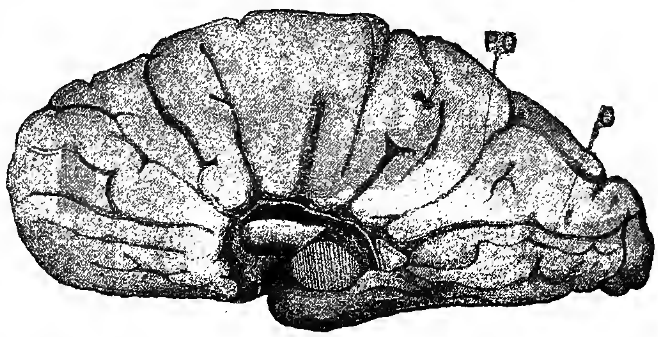


Fig. 6.—Reproduction of a figure by Onufrowicz, depicting a human brain in which the corpus callosum was absent. *PO.*, parieto-occipital fissure; *C.*, calcarine fissure.

Onufrowicz ‡ (fig. 6), show the retention of the transitory fissural arrangement in the most marked manner.

But it is not on the inner surface alone that the transitory fissures may be retained. Hans Virchow§ has described and figured a very extraordinary brain (fig. 7), in which the corpus callosum was absent in connexion with hydrocephalus internus. The fissural type on both aspects of the

* Archiv f. Psychiatrie, vol. viii., pt. 2, 1878.

† Glasgow Medical Journal, 1885.

‡ Archiv f. Psychiatrie, vol. xviii., 1887.

§ "Ein Fall von angeborenem Hydrocephalus Internus, zugleich ein Beitrag zur Mikrocephalen Frage," v. Kölliker's Festschrift, 1887, Leipzig, p. 305.

cerebral hemisphere is that of the period of the transitory fissures. With reference to those on the outer surface he remarks: "Ebenso auffallend ist die Abweichung vom Typus bei den Furchen. Es ist gewissermassen der normale Typus gänzlich aufgehoben und durch einen neuen Typus ersetzt, welcher an die Zustände beim ersten Auftreten der Furchen dadurch erinnert, dass eine Tendenz zu radiären Anordnung die Furchen beherrscht." But it is not an exaggeration of the permanent "radiären Primärfurchen," of Reichert, Bischoff and Pansch, that this brain shows but the retention of the much earlier transitory fissures.

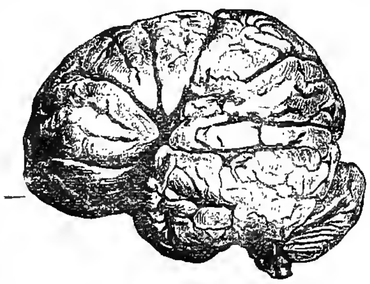


FIG. 7.
Outer surface of a brain described and figured by Dr. Hans Virchow.

In Dr. Bruce's case of absent corpus callosum, the fissure of Rolando is situated very far forward, and is continued over the upper border of the cerebrum on to the mesial face of the hemisphere. We might naturally question whether or not this is the true fissure of Rolando, or merely a furrow produced by the retention of one of the primitive transitory fissures. Such a fissure as is represented in fig. 11, Pl. I., would stand for it. The direction of the fissure of Rolando in Dr. Bruce's case, viz. from above downward and backward, would lend some support to this view.

Zuckerkandl* describes and figures the misshapen brain of a child (fig. 8), in which there is a considerable amount of convolutionary disturbance. On the inner face of both hemispheres the fissures are arranged in a radiated manner, and in the left hemisphere there is little or no trace of the calloso-marginal sulcus. This abnormal condition Zuckerkandl believes to have been brought about by pressure of the uterine wall upon the fœtus, through a deficiency in the quantity of amniotic fluid. The skull had assumed that form which one observes in the "artificially deformed crania of the Huancas." If Zuckerkandl be right in his explanation, the case is one of high interest, because the radial fissures on the inner face of the

* "Anatomie des menschl. Körpers," Ueber Veränderungen der Gehirnoberfläche hervorgerufen durch Druck von Seite des Uterus. Medizinischer Jahrbücher herausgegeben von der k. k. Gesellschaft der Ärzte, 1883, III., IV. Heft., p. 438.

hemispheres have, in all probability, been produced by a retention of the transitory fissures; and it would be a matter of high importance if we could prove that pressure continuously applied to the head of the early fœtus would lead to the preservation of the temporary furrows. At the same time I am very doubtful if external pressure has had anything to do with the continuance of the temporary furrows on the mesial face of this brain. If the figures which accompany Zuckerkandl's Paper be correct the posterior part of the corpus callosum is absent, and the abnormal arrangement of the fissures on the inner surface of the hemispheres is more likely to be associated with this condition. This is rendered all the

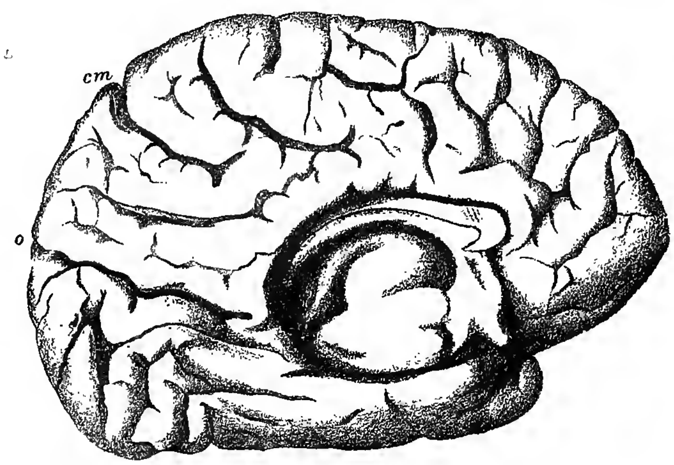


Fig. 8.—Abnormal brain figured by Zuckerkandl.

more probable from the fact that it is in the back part of the cerebrum that the departure from the normal arrangement is most strongly accentuated.

One other example of what appears to me to be a retention of the early transitory fissures I may be allowed to give. It is in the brain of a Cretin, the photograph of which Professor Victor Horsley has been so good as to place in my hands. This I have reproduced in the accompanying figure (fig. 9). Unfortunately there is no history of the case. The only information which we have of it is that furnished by the photograph. We cannot tell, therefore, whether the corpus callosum was properly developed

or not; but a series of deep, transverse, gaping fissures are seen on the basal aspect of the hemisphere, cutting into the temporal and occipital lobes.

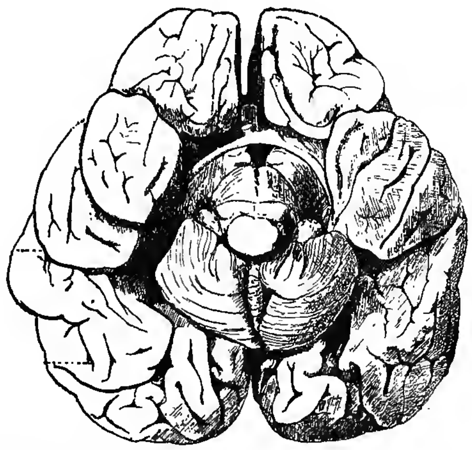


Fig. 9.—Brain showing a series of abnormal transverse fissures on the under surface of the temporal lobes. From a photograph supplied by Prof. V. Horsley.

These abnormal incisions I regard as being produced by a retention of the temporary fissures of the early fœtal brain.

Although it has no direct connexion with what goes before, I may as well mention at this stage that in the course of my examination of the series of specimens in the museum of University College, London,

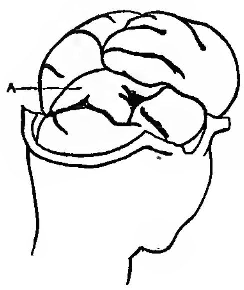


Fig. 10.

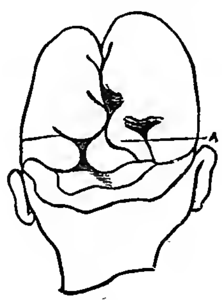


Fig. 11.

I met with a very remarkable deformity in the posterior part of the right cerebrum of a fœtus between the third and fourth month. A hollow outgrowth projected backward over the mesencephalon, upon the

upper surface of which it was closely adapted. It was spread out, so as to cross the mesial plane, and its posterior border showed an angular deficiency which gave it a forked appearance (fig. 10 A). The under-wall of this outgrowth or lappet was formed of an epithelial layer only. Its precise attachment to the cerebrum could not be made out without destroying the specimen, but it appeared to be attached by a stalk to the under and back part of the cerebrum. The posterior part of the temporo-sphenoidal lobe, which was completely separated from the remainder of the cerebrum by a deep temporary fissure, overlapped this stalk, and hid its connexions.

It is difficult to imagine what the further history of such an embryo would have been had it survived. The deformity cannot be very rare, as Richter has figured a specimen which shows a very similar condition (fig. 11 A).

V. **Relation of the Appearance and Obliteration of the Transitory Fissures to the Growth of the Cerebral Hemispheres and the Mapping-out of an Occipital Lobe.**—The transitory infoldings of the early hemisphere wall play an important part in the general growth of the cerebrum and in the appearance of an occipital lobe. When we read the accounts which are given of the formation of the occipital lobe, an impression is conveyed to the mind that this part of the cerebrum is a local outgrowth or bud which grows backward from the hinder and upper part of the hemisphere about the beginning of the fourth month; in other words, that it is a secondary formation.

Such is the view which is advanced by Schwalbe; and he may be regarded as giving expression to the opinion which is held by many anatomists on this question. He says:—"We have to separate on developmental grounds the annular lobes (ringförmigen Lappen) from the occipital lobes, which have a *secondary* origin, and which are only present, characteristically developed, in Man and the Apes."*

Reichert† considers that the occipital lobe must be regarded upon an

* Lehrbuch der Neurologie. Erlangen, 1881, p. 534.

† Der Bau des menschlichen Gehirns. Leipzig, 1861, p. 80.

altogether different genetic footing from the annular "Grundform" of the mantle. He regards it as an accessory lobe (*Nebenlappen*) or accessory end (*Nebenende*) of the hemisphere.

According to Ecker,* the occipital lobes do not exist in the third month; they only appear in the fourth month. He applies the term "Aussackung," or pouching out, to the process of formation. Pansch† speaks of the occipital lobe as a hinder "Auswuchs," which, taken along with the context, clearly shows that he regarded the production of the occipital lobe as due to local growth restricted to the hinder end of the hemisphere. Mihalkovics‡ calls the occipital lobe a "Nebenfortsatz," or accessory projection, and frequently refers to the early condition of the hemisphere in which, as he remarks, it only consists of frontal, temporal, and parietal lobes. Krause§ applies the term "secundärer Auswuchs" and "secundäre Bildung" to it; and Richter,‖ who, as we have seen, admits the very early appearance of the calcarine and parieto-occipital fissures, nevertheless speaks as if he regarded the budding-out of the occipital lobe to be a process analogous to the outgrowth of the optic vesicle.

But, whilst the majority of anatomists would appear to take this view of the formation of the occipital lobe, there are two who have expressed themselves in very different terms. I refer to v. Kölliker and to His. The opinion which v. Kölliker ¶ holds regarding the origin of the calcarine and parieto-occipital fissures necessarily entails, as a part of it, the existence from a very early period of a portion of the brain which corresponds to an occipital lobe. His** gives an admirable account of the mode in which the occipital lobe is moulded into shape. He explains that it owes its existence to the strong development of the "Brückenkrümmung," which, in the primate brain, carries the cerebellum and pons downward and forward.

* Archiv f. Anthropologie, Dritter Band, 1869, p. 208.

† *Ibid.*, p. 232.

‡ Entwicklungsgeschichte des Gehirns, 1887, p. 111.

§ Handbuch der menschlichen Anatomie, Zweiter Band, 1879, pp. 728, 729.

‖ Archiv f. Path. Anat., Virchow, 1887, p. 421.

¶ Entwicklungsgeschichte des Menschen und der höheren Thiere, 1879.

** Unsere Körperform, 1875, Neunter Brief, p. 115.

His whole description shows that he regards the appearance of the occipital lobe as being due to a general, and not to a local growth.

It is also right to mention that Bischoff took up a somewhat similar position with regard to the occipital lobe. He says: "Ich sehe mich auf diese Weise im Widerspruch mit Arnold und Reichert, welche, wie ich oben angegeben, den Hinterlappen nur als einen späteren Auswuchs oder Verlängerung des hinteren Theiles der embryonalen Hemisphären betrachten. Ich behaupte im Gegentheil, dass derselbe wie alle übrigen Theile dieser Hemisphären sich allmählig aus dem anfangs noch nicht in einzelne Lappen unterscheidbaren Keime da entwickelt, wo er später bemerkt wird. Ja, die Selbstständigkeit dieses Hinterlappens wird durch das frühe Auftreten der inneren senkrechten Occipital- und der Hippocampus (calcarine) Spalte, sowie der transitorischen äusseren senkrechten Occipital-Furche ganz besonders bewiesen."*

There are many points which indicate in the clearest manner that the occipital lobe is not a local secondary outgrowth which has sprouted out from the hinder end of the cerebral hemisphere in a bud-like fashion. From the end of the second to about the beginning of the fourth month the young embryonic human cerebrum presents the characteristic bean-shaped outline which has led German authors to apply to it the term "ringförmigen Lappen." At this stage the primate cerebral hemisphere resembles in outline the adult condition of the hemisphere in most quadrupeds. A further similarity may be noted in the fact that the Sylvian fissure in the quadruped brain stands upright and nearly vertical, and thus corresponds with the vertical direction of the Sylvian fossa in the fœtal primate cerebrum. But as the occipital lobe in the latter takes form, the Sylvian fossa becomes more and more oblique, which clearly shows that the growth is not restricted to the hinder end of the hemisphere, but affects it from one end to the other—in other words, that it is interstitial and general.

The shape of the occipital part of the cerebrum depends upon the restricted space it is called upon to occupy above the cerebellum. As it is pushed backward by the general cerebral growth it is moulded into shape

* Die Grosshirnwindungen des Menschen. Abh. d. 11. Cl. d. bay. k. Ak. d. Wiss., x., Bd. 11. Abth., p. 416.

by its surroundings, and its very existence depends, as His has pointed out, upon the strong "Brückenkrümmung" of the embryonic primate brain. This backward thrusting also of the posterior part of the hemisphere is chiefly instrumental in preserving the precursory calcarine and parieto-occipital fissures.

The transitory fissures on the outer surface of the cerebral hemisphere make their appearance, as we have noted, about the beginning of the third month, and undergo obliteration toward the end of the fourth month, viz. at the time when the occipital lobe becomes clearly mapped out as a distinct portion of the cerebrum. This is a circumstance which is deeply suggestive and significant. The majority of observers who have studied the transitory fissures are agreed in ascribing their formation to a more rapid growth of the hemisphere wall than of the skull-capsule within which it is enclosed. The necessary result of such a growth-restraint is, that the thin wall of the hemisphere becomes folded along lines which run at right angles to the axis of growth-energy. But no one has attempted to explain why, at this period, the growth-rate of the skull-capsule and of the contained cerebrum should be at variance with each other. We may, I think, take for granted that the cerebral infoldings occur only in the embryonic brain of primates. Schmidt failed to observe them in sheep, oxen, or pigs, although he thought he saw weak traces of them in the embryo of the cat.* This latter statement I cannot verify. Although I have looked for the transitory fissures in cat and dog embryos of different stages, I have never seen any infolding of the cerebral wall that could be compared with those we have described in connexion with the human brain. It is, however, a question which requires further investigation.

The temporary fissures, therefore, are in all probability peculiar to the primates; they occur at a stage of growth prior to the appearance of a well-marked occipital lobe; the great majority of them are effaced when this portion of the cerebrum is moulded into shape; and, lastly, their formation appears to be due to a want of harmony between the growth-rate of the cerebrum and of the skull-capsule. How can these facts be explained?

* "Beiträge zur Entwicklungsgeschichte des Gehirns," Zeitsch. f. Wiss. Zool., Bd. xi., 186.

We may assume that, although cranial and brain-growth, as a rule, go on smoothly and evenly and in perfect harmony with each other, all steps toward an advance of development must be initiated within the brain, and that, for a time at least, the enclosing skull-capsule will resist these. This being granted, we can readily understand that the tendency towards the cerebral growth which gives rise to a well-mapped out occipital lobe is more firmly impressed upon the brain than upon the skull. When the primate head reaches in its development the quadruped stage, the cerebrum goes on, without any intermission in its growth, towards the higher development and the formation of a distinct occipital lobe. The cranium, however, pauses in its growth. But this quadruped pause marks only a stage in its evolution; it is merely temporary, although it is of sufficient duration to produce the infoldings of the cerebral wall.

But against this view it may be argued that the temporary fissures appear before the third month on the mesial face of the hemisphere. It must be remembered, however, that the conditions of growth on the mesial face are different from those on the outer surface of the hemisphere. In the first place, the inner wall is distinctly thinner than the outer wall; and, as His has pointed out: "Through the hemispheres being opposed to each other in the mesial plane, and the space thus restricted, they exercise an influence on each other. Instead of being able by bulging to push themselves out, they are required to adapt themselves to the even and plain bounding surface." *

I have already referred (p. 22) to the preservation of the temporary fissures on the outer surface of a brain described by Dr. Hans Virchow. I have reproduced a tracing from the photograph which the author gives of this brain, and it is a matter of extreme interest to observe that the cerebrum presents an outline similar to that of a brain between the third and fourth months of intra-uterine life. The growth which would have led to the mapping-out of a distinct occipital lobe has been arrested, and, consequently, the temporary fissures have been retained. The general similarity in outline to that of a quadruped brain is very marked.

Further evidence in support of the view which I have advanced might

* Unsere Körperform, Neunter Brief, p. 112.

be adduced from the fact that variations in the capacity of the hinder part of the cranium are much greater than those in the fore part.*

Considering, then, that the occipital lobe in primates owes its origin to a general growth of the cerebral hemisphere, and not to the sprouting out of a local bud from its hinder end, it would be wrong to deny the presence of a corresponding portion of the cerebrum in the lower mammals. From this point of view, Benedikt† has some ground for his assertion that in the mammalia generally there is an occipital lobe. Upon his further statement that the calcarine fissure is also developed in brains below the primates, I am not in a position at present to offer an opinion.

With the expansion of the cranial cavity the temporary fissures become obliterated by the partial opening out of the infoldings. The cerebrum at the same time increases in length, and the occipital lobe comes clearly into view. But the increase in length is not so great as that which would be produced by the complete opening out of all the transitory infoldings of the cerebral wall. This can readily be proved by measuring the depth of the fissures and calculating the increase in length which the cerebrum has undergone between the time when these fissures were present and the period when it is entirely smooth. The question, therefore, arises—What becomes of the deeper parts of the folds? To this, I suspect, we cannot offer a satisfactory answer. We have seen that Meckel, the original observer of these transitory fissures, was of opinion that their obliteration was due to the growing together of their opposed surfaces. Certain it is that the deepest part of the bottom of the infolding cannot reach the surface of the brain in every case unless it does so by a partial absorption of the walls of the fold. This, combined with the partial opening out of the fissures, may serve to account for their disappearance. Further research, however, is required in connexion with this part of the inquiry, and this can only be conducted by one who has a large amount of particularly well-preserved material at his disposal.

Richter has advanced the theory that the choroid plexuses, as they

* Virchow's Gesammelte Abhandlungen zur wissenschaftlichen Medicin, 1856.

† Der Hinterhauptslappen der Säugethiere, von Dr. Moritz Benedikt (Wien). Sep. Abdr. a. d. Centralbl. f. d. Med. Wissensch., 1877, No. 10.

expand in size, may have some influence in bringing about the unfolding of the temporary fissures, and in smoothing out the surface of the cerebral hemisphere.

VI.—**Parieto-occipital and Calcarine Fissures in the Adult.**—The parieto-occipital and calcarine fissures form upon the mesial aspect of the posterior part of the adult cerebral hemisphere a ≻-shaped figure. In this we recognise a "stem" with two diverging branches. The "stem" is prolonged obliquely downward and forward, and cuts into the gyrus fornicatus. In its lower half it is placed on the tentorial surface of the human cerebrum, while its upper half occupies the mesial surface. Of the two diverging branches the parieto-occipital, on superficial inspection, appears to run more in a direct line with the "stem" than the calcarine branch. It ascends to the upper border of the hemisphere, which it incises deeply, forming on the cranial aspect of the cerebrum the external parieto-occipital fissure. The length of this external fissure corresponds with the depth of the internal fissure. Frequently the upper extremity of the parieto-occipital fissure divides, in which case two branches cut the upper border of the hemisphere. Of these the anterior is usually a shallow offset.

The calcarine branch proceeds backward in a horizontal direction toward the occipital pole. On this it ends by dividing into an ascending and descending branch. These are usually placed at right angles to the parent trunk. This terminal part of the calcarine fissure lies at the bottom of the groove, which on the right cerebrum marks the continuation of the longitudinal sinus into the lateral sinus.

Both the calcarine and parieto-occipital branches of this fissural system lie in the human brain entirely on the mesial surface of the cerebrum, altogether above the low-lying border which intervenes between this surface and the tentorial surface.

The study of the parieto-occipital and calcarine fissures is surrounded with many difficulties, and it is necessary to enforce, at the very outset, the distinction which I have drawn between the "stem" and the two branches. It is one of deep morphological importance, as we shall see

later on, when we come to deal with the development of these three parts. In order to pave the way for this, as well as to render certain obscure points clear, it is necessary to examine closely the condition which is present in the adult brain.

When we open up the entire extent of the ≻-shaped fissure in the adult brain, so as to obtain a continuous and complete view of its bottom (Pl. IV., fig. 5), we observe that the "stem" is much the deepest part. Further, we note that it is not directly continuous with the parieto-occipital branch. A high, deep annectant gyrus (gyrus cunei of Ecker, or inferior internal "*pli de passage*," of Gratiolet) extends from the apex of the cuneus across the bottom of the lower portion of the parieto-occipital fissure to the opposite bank, which at this point is formed by the gyrus fornicatus. Frequently this deep gyrus cunei as it runs forward divides into two smaller gyri. Of these, the lower goes to the gyrus fornicatus and the upper to the lower part of the præcuneus. The deep gyrus cunei forms then a barrier between the "stem" and the parieto-occipital limb (Pl. IV., fig. 5, *c.* 1, *c.* 2).

As a general rule, the "stem" runs backwards for a short distance in the calcarine branch—forming about half an inch of its fore-part—but soon it is arrested by a deep annectant gyrus, which extends from the apex of the cuneus, across the bottom of the calcarine fissure, to the opposite bank formed by the gyrus lingualis. This annectant may be termed the *anterior cuneo-lingual gyrus* (Pl. IV., fig. 5, *a. l.*).

The "stem" varies in length, but as a rule it will be found to be about 40 mm. long. The facts stated above in regard to it may be put briefly thus: the apex of the cuneus gives off two deep annectant gyri, viz. the gyrus cunei and the anterior cuneo-lingual gyrus. The "stem" by its hinder end is carried into the cuneate lobe between these gyri, whilst by its anterior end it cuts into the gyrus fornicatus. The gyrus cunei forms a barrier between the parieto-occipital fissure and the "stem," whilst the gyrus cuneo-lingualis anterior is interposed between the "stem" and the posterior part of the calcarine fissure.

For reasons which will be afterwards evident we may term the "stem" the fissura calcarina anterior, and the portion of the calcarine fissure behind this the fissura calcarina posterior.

The posterior calcarine fissure cannot properly be regarded as extending further forward than the anterior cuneo-lingual gyrus. Not only is this seen to be the case in the adult brain when the fissure is freely opened up, and the bottom exposed along its whole length (Pl. IV., fig. 5, c. C."); but it is still more forcibly brought under our notice when we study the development of the fissure. Its length varies with that of the "stem," or anterior calcarine fissure, because the anterior cuneo-lingual gyrus is not by any means constant in its position, and as it slides forwards or backwards it affects the length of the two portions of the fissure in question. As a rule the posterior calcarine fissure is shorter than the "stem" and we may give its average length as being about 35 mm. Further the posterior calcarine fissure is much shallower than the "stem" or anterior part; and it is divided into two parts by a deep annectant, which traverses its bottom, and connects the cuneus with the posterior part of the gyrus lingualis. This annectant may be termed the *posterior cuneo-lingual gyrus* (Pl. IV., fig. 5, *p. l.*). The part of the calcarine which it cuts off comprises little more than its hinder forked extremity.

The parieto-occipital fissure is deeper than the calcarine, but it is, as a rule, not so deep as the "stem." In what may be considered the normal arrangement, a feeble deep annectant crosses it at the junction of its upper and middle thirds, and connects the cuneus with the præcuneus (fig. 12, *i.c.*). In addition to this its opposing walls frequently present interlocking gyri.

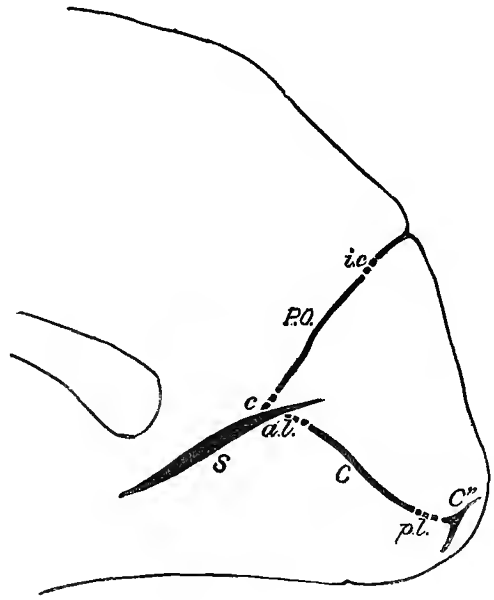
In the parieto-occipital and posterior calcarine fissures the opposing walls are vertical; the fissures, therefore, incise the cerebrum at right angles to the surface. This is not the case, however, with the "stem." It cuts obliquely into the hemisphere in such a manner that it undermines the gyrus lingualis, which therefore comes to overlie the gyrus cunei and the apex of the cuneus.

The arrangement (fig. 12) which I have described above may be regarded as being that most commonly present. It is by no means, however, the only arrangement that may be met with. In 127 hemispheres (including ten negro brains, a considerable number of children's brains, and fourteen brains from fœtuses about the eighth month of development) it was present 43 times or in 33·8 per cent.

The most frequent deviation from this condition is the absence of the deep gyrus intercuneatus, which breaks up the parieto-occipital fissure This occurred in 47 per cent. of the cases examined. The gyrus cunei is extremely constant. In only 3·1 per cent. was it absent, and of course in these cases the parieto-occipital fissure ran without let or hindrance into

Fig. 12.

S., . .	the "stem."
P.O., .	parieto-occipital fissure.
C., . .	fore-part of the posterior calcarine fissure.
C.", . .	hinder-part of the posterior calcarine fissure. (The *fissura extrema* of Seitz.
i.c., . .	deep gyrus intercuneatus.
c., . .	deep gyrus cunei.
a.l., . .	anterior deep gyrus cuneo-lingualis.
p.l., . .	posterior deep gyrus cuneo-lingualis.



Present 43 times in 127 hemispheres, *i. e.* in 33·8 per cent.

Right side, ...	39	per cent.
Left side, ...	27·6	,,
Males, ...	40·3	,,
Females, ...	24·6	,,
Negroes, ...	20	,,
Fœtesus between eight months and full-time, ...	7	,,

the "stem." The cuneo-lingual gyri are also very rarely absent. The anterior gyrus was absent in 7·8 per cent.; and in these cases the fore-part of the posterior calcarine fissure and the "stem" were directly continuous. In only 10 per cent. was the posterior gyrus absent so as to render the two parts of the posterior calcarine fissure absolutely continuous.

But occasionally one or other of these annectant gyri come altogether to the surface, so as to constitute a complete break in the continuity of the fissure. It is the posterior cuneo-lingual gyrus that most frequently shows this condition; and the natural effect is that the posterior forked extremity of the posterior calcarine fissure is cut off from the fore portion, and forms an isolated short vertical sulcus on the occipital pole, and at the bottom of the venous groove in the case of the right hemisphere. This occurred in no less than 31·5 per cent. of the hemispheres examined. This variety was particularly common in the negro brain, and in the fœtus.* It was noticed in 50 per cent. of the former and 60 per cent. of the latter. We shall have occasion to allude to this again when we come to discuss the development of the calcarine fissure.

In five cases only, or in other words in 3·9 per cent., did the gyrus cunei reach the surface, and completely cut off the parieto-occipital fissure from the stem (Pl. IV., figs. 6 and 7, *c.*); and it should be noted that in each of these, other peculiarities were present. In three cases (2·3 per cent.), and no more, did I find the anterior cuneo-lingual gyrus on the surface, and the posterior calcarine fissure quite separate from the "stem."

I have only once seen the gyrus inter-cuneatus reach the surface in the same way as the others. Sernoff, of Moscow,† has also figured such a case.

Of course many different combinations of the various conditions of this fissural system which we have described above are possible. That which I have noted as normal, or in other words, that which is most frequently seen, is the arrangement in which all the annectant gyri are present, but concealed at the bottom of the fissure. The combination which comes next to this in point of frequency is that indicated in the accompanying

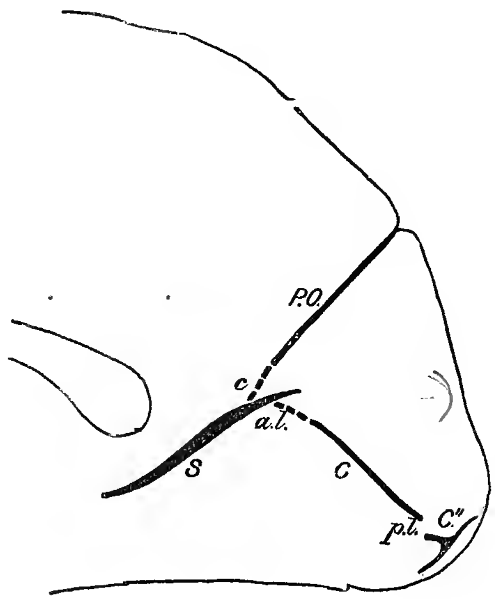
* In connexion with this it is interesting to note that in the two Fuegian brains described by Seitz, the hinder part of the posterior calcarine fissure is represented as being separate and distinct in three out of the four hemispheres. "Zwei Feuerländer-Gehirne"; Zeitschrift für Ethnologie, 1886. See his figures 3, 7, and 15.

† "Individual Types of the Convolutions of the Human Brain": Moscow, 1877, p. 71, fig. 69. The same author has also figured a brain in which the posterior cuneo-lingual gyrus is on the surface (p. 71, fig. 70); and another in which the anterior cuneo-lingual gyrus is on the surface (p. 72, fig. 72).

diagram (fig. 13). It is present in 15·7 per cent. The gyrus intercuneatus is absent, and the posterior gyrus cuneo-lingualis is on the surface.

Fig. 13.

S., . "stem," of anterior calcarine fissure.
P.O., . parieto-occipital fissure.
C., . . fore-part of posterior calcarine fissure.
C.'', . . hinder-part of the posterior-calcarine fissure.
c., . . gyrus cunei.
a.l., . . deep gyrus cuneo-lingualis anterior.
p.l., . . posterior cuneo-lingual gyrus *on the surface.*

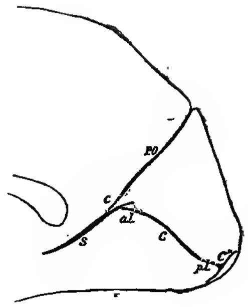


Present in 20 hemispheres, *i. e.* in 15·7 per cent.

Right side, ...	15·9 per cent.
Left side, ...	15·5 ,,
Males, ...	17·8 ,,
Females, ...	13·3 ,,
Negroes, ...	50 ,,
Fœtuses from eighth month to full time, ...	60 ,,

The next combination is one very similar to the foregoing—the only difference being the fact that the posterior cuneo-lingual gyrus does not reach the surface, but is concealed within the calcarine fissure. This was present in seventeen cases, or in 13·3 per cent. (fig. 14).

FIG. 14.



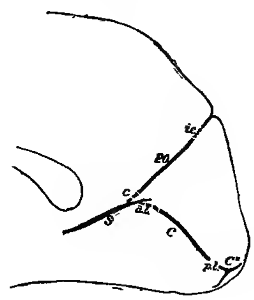
S.,	. .	"stem," or anterior calcarine fissure.
P.O.,	.	parieto-occipital.
C.,	. .	fore-part of posterior calcarine fissure.
C",	. .	hinder-part of the posterior calcarine fissure.
i.c.,	. .	deep gyrus inter-cuneatus.
a.l.,	. .	deep anterior gyrus cuneo-lingualis.
p.l.,	. .	posterior gyrus cuneo-lingualis.

Present in 17 hemispheres, *i. e.* in 13·3 per cent.

Right side,	11·6 per cent.
Left side,	15·5 ,,
Males,	12 ,,
Females,	15 ,,
Negroes,	10 ,,
Fœtuses between eight months and full time,	7·1 ,,

Another combination which is tolerably frequent is that in which all the annectants are present, but the posterior cuneo-lingual gyrus is on the surface. This was present 12 times, or in 9·4 per cent. (fig. 15).

FIG. 15.



S.,	. .	"Stem," or anterior calcarine fissure.
P. O.,	.	parieto-occipital.
C.,	. .	fore-part of posterior calcarine fissure.
C.",	. .	hinder-part of the posterior calcarine fissure.
i.c.,	. .	deep gyrus inter-cuneatus.
a.l.,	. .	deep anterior gyrus cuneo-lingualis.
p.l.,	. .	posterior gyrus cuneo-lingualis.

Present in 12 hemispheres, *i. e.* in 9·4 per cent.

Right side,	11·6 per cent.
Left side,	6·8 ,,
Males,	8·9 ,,
Females,	10 ,,
Negroes,	10 ,,
Fœtuses between eighth month and full time,	14·3 ,,

A somewhat important combination of the different parts of the parieto-occipital and calcarine fissures is that in which the anterior cuneo-lingual gyrus is absent, and the gyrus cunei and posterior cuneo-lingual gyrus present (fig. 16). This was seen in ten hemispheres, or in 7·8 per cent. In six of these the posterior cuneo-lingual gyrus was concealed within the calcarine fissure; in four it was on the surface.

A condition exactly the opposite of the foregoing is that in which the cuneate gyrus is absent, and a direct continuity thus established between

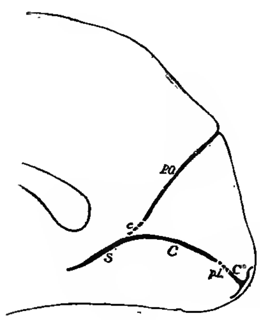


Fig. 16.

S., . . "stem," or anterior calcarine fissure.
P.O., . parieto-occipital fissure.
C., . . fore-part of the posterior calcarine fissure.
C.", . . hinder part of the posterior calcarine fissure.
c., . . gyrus cunei.
a.l., . . gyrus cuneo-lingualis anterior.
p.l., . . gyrus cuneo-lingualis posterior.

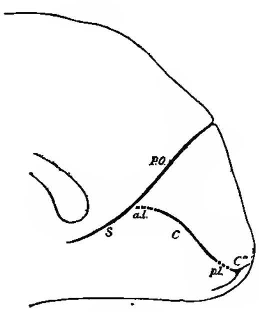


Fig. 17.

the "stem" and the parieto-occipital fissure. In this case the two calcarine annectant gyri are present (fig. 17). This occurred in four hemispheres, or in 3·1 per cent.

Several other combinations of the parts concerned in this fissural system were observed; but as the conditions under which they are brought about have been referred to, and as they occur very seldom we need not enter into detail in regard to them. Three very unusual arrangements of the fissures, however, must be specially noticed, inasmuch as they bear directly upon certain points which we shall be dealing with when we come to speak of the development of the parieto-occipital and calcarine fissures. The accompanying diagrams will serve to make the conditions met with in these cases apparent.

In the 127 hemispheres examined I met four in which the condition

present in fig. 18 is represented. The manner in which it is produced is evident. The gyrus cunei is on the surface; and the hinder end of the stem is prolonged upward between the gyrus cunei and the concealed gyrus cuneo-lingualis anterior for a considerable distance into the cuneate lobe. In this position it is apt at first sight to be mistaken for the parieto-occipital fissure.

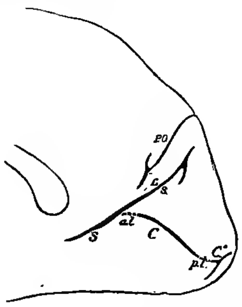


FIG. 18.

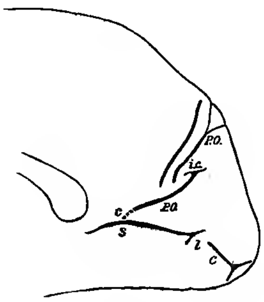


FIG. 19.

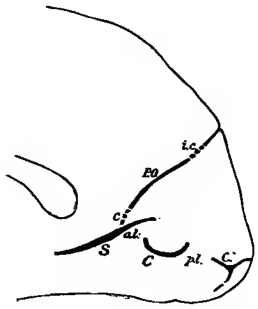


FIG. 20.

S., "stem"; *P.O.*, parieto-occipital; *C.*, fore-part of posterior calcarine; *C.''*, hinder-part of posterior calcarine; *c.*, gyrus cunei; *i.c.*, gyrus inter-cuneatus; *a.l.*, anterior cuneo-lingual gyrus; *p.l.*, posterior cuneo-lingual gyrus.

In only one hemisphere was the arrangement represented in fig. 19 exhibited. Here the parieto-occipital fissure is broken into two by the elevation of the intercuneate gyrus to the surface (*i. c.*), and the anterior cuneo-lingual gyrus is absent. In front of the parieto-occipital we note a shallow furrow parallel to it. In cases in which this furrow deviates decidedly from the normal type there appears to be a tendency for it to become double. This is not the only case of doubling of the parieto-occipital fissure which I have seen.

Fig. 20 exhibits a very interesting arrangement—a persistence, as we shall afterwards see, of a fœtal condition—in which the two parts of the posterior calcarine fissure are completely cut off from each other as well as from the "stem." The tsem also is carried up between the cuneate and anterior cuneo-lingual gyri for a considerable distance into the cuneate lobe.

A very essential point which must now be decided is the relation which this system of fissures bears to the calcar avis or hippocampus minor of

the posterior horn of the lateral ventricle in the adult brain. The parieto-occipital fissure above the "stem" has no relation whatever to the ventricular cavity, because above the level of its junction with the "stem" the wall of the hemisphere has become solid through the increase of the white substance; nor has the posterior calcarine fissure (*i. e.* the calcarine fissure behind the anterior cuneo-lingual gyrus) anything to do in the production of this intra-ventricular bulging. The calcar avis is formed entirely by the back part of the "stem," or, as we have termed it, the anterior calcarine fissure.

VII. **Parieto-occipital and Calcarine Fissures in the Ape.**—In the ape the stability and great depth of the calcarine fissure shows that it is of vastly greater morphological importance than the parieto-occipital fissure, which is extremely variable, and often insignificant. In the chimpanzee, the gyrus cuneus is on the surface (fig. 22, p. 43); in this manner the two fissures are completely separated from each other. This condition may also occasionally be seen in the human brain (3·9 per cent.).* In the orang and gibbon the gyrus cunei may either be on the surface as in the chimpanzee, or it may be concealed at the bottom of the fissure. In an orang's brain in my possession, the right hemisphere shows a superficial communication between the parieto-occipital and calcarine fissures (fig. 21, p. 43), whilst on the opposite side the two fissures are completely separated by the rise of the gyrus cuneus to the surface. Under no circumstances whatever do we ever find the gyrus cunei completely absent in the anthropoid brain, and thus there never occurs a perfectly free communication between the calcarine and parieto-occipital fissures. The question now comes to be: Is there any evidence which would seem to indicate that the calcarine fissure in the ape is composed of two fundamentally distinct parts—a "stem," or anterior calcarine fissure, and a posterior calcarine fissure? Throughout its whole length the calcarine fissure in both the chimpanzee and the orang presents very nearly the same depth. Its walls are smooth, and there is not a vestige of a deep annectant gyrus to be seen crossing its

* Parker has also observed the gyrus cunei on the surface in one negro brain. Proc. Acad. Nat. Sci. Phila., 1878.

bottom at any point so as to connect its opposite banks with each other. Further, when we study the relation which this fissure presents to the calcar avis, we observe that the entire length of this ventricular eminence corresponds with that portion of the sulcus which lies opposite to it. Such being the case are we to conclude that the calcarine fissure in the ape represents both "the stem" and the posterior calcarine fissure of man; and if not, of which part is it the equivalent? I am of opinion that it only represents the "stem;" and I believe that I shall be able to prove this assertion when we come to deal with the development of the fissure in the human brain. The entire length of the precursor of the calcarine fissure in the early human fœtus is the equivalent of the calcarine fissure of the ape; but in man, the posterior portion of this becomes obliterated, whilst the anterior part is retained as the "stem." In the place of the portion which is abolished, and at a much later date, the posterior calcarine sulcus is formed.

The remarkable depth of the calcarine fissure in the apes—a depth which appears to be relatively greater in low apes than in the high apes—is thus easily accounted for when we consider that it is formed by a retention of the whole length of its precursor, or, in other words, that it is developed as a complete fissure from one end to the other.

In the orang,* chimpanzee,† and gibbon,‡ and probably also in the gorilla, there appears to be a tendency towards the assumption of a condition which approaches somewhat towards the human arrangement. In many cases the calcarine fissure is shortened. It is then confined entirely to the mesial and tentorial surfaces of the hemisphere, and does not extend beyond the upper border to the outer surface. Its hinder extremity turns upward, and ends in a forked extremity (fig. 21). This condition presents a striking similarity to that which we have figured in page 39 (fig. 18), and which occurred in four human brains. In these the "stem"

* Bischoff—"Ueber das Gehirn eines Orang-outan," Sitzung der Math.-Phys. Classe vom 17. Juni, 1876. K. bayer. Akad. *Vide* Pl. IV., fig. 6.

† Bischoff—"Ueber das Gehirn eines Chimpansé," *Ibid.*, 4 Februar, 1871. *Vide* fig. 4.

‡ Bischoff—"Beiträge zur Anatomie des Hylobates leuciscus." Aus den Abhandlungen der k. bayer Akad. der W. II. Cl. X. Band. III. Abth. *Vide* Pl. II., fig. 4.

was prolonged upward for a considerable distance into the cuneus, and divided it into two portions. Examine also Pl. IV., figs. 6 and 7. Of course in the anthropoid ape there is never any trace of the fissure which in man we have named the posterior calcarine sulcus.

The condition which we have just described as occurring frequently in the anthropoid is the rule in many of the lower apes. The calcarine fissure fails to reach the upper margin of the hemisphere. It is important to note that in no case does the calcarine fissure run directly to the occipital pole. In both high and low apes where it extends beyond the

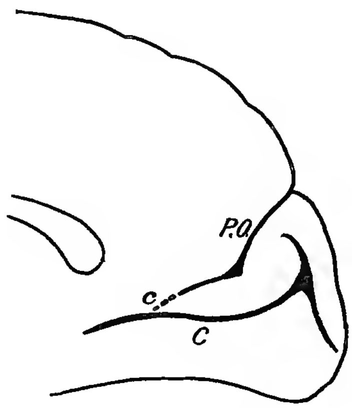


FIG. 21.—ORANG

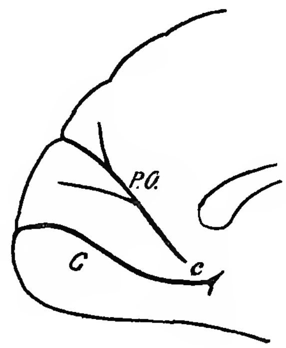


FIG. 22.—CHIMPANZEE.

P.O., parieto-occipital fissure; *C.*, calcarine fissure; *c.*, gyrus cunei.

mesial face on to the outer surface it cuts the mesial border of the hemisphere a short distance in front of the occipital pole.

From what we have said it will be evident that the cuneus in the ape does not present the same morphological value as the corresponding portion of brain surface in man. Only the anterior portion—the part which lies in front of the stem in fig. 18—is present in the ape. The hinder part appears to be absent, or blended with the gyrus lingualis.

In connexion with this, the two hemispheres figured in Pl. IV. (figs. 6 and 7) are very instructive. They were taken from a new-born full-time child, and exhibit several marked ape-like conditions. Note especially the

fact, that in each case the gyrus cunei is on the surface, and, further, that the "stem" of the calcarine fissure is prolonged up into the cuneus in a very ape-like manner.

To put the matter briefly, then, we may say: (1) that the calcarine fissure of the ape's brain corresponds with the "stem" of the $\prec$-shaped fissure in the adult human brain, and with the entire length of the precursor of the calcarine fissure in the human fœtal brain; (2) in the human brain the posterior part of the precursor of the calcarine fissure of the fœtus is obliterated, and in its place a secondary sulcus is laid down at a later date (the posterior calcarine sulcus). In the brain of the ape there is no representative of the latter sulcus.

The position of the calcarine fissure in the ape is very different from that of the corresponding fissure in man. Almost the entire $\prec$ shaped fissure in the human brain lies upon the mesial surface of the hemisphere. The lower half of the "stem" is the only part which occupies a place on the tentorial surface. In the ape, however (both in the higher and lower forms), the entire length of the calcarine fissure, with the exception of its hinder end, is situated on the tentorial face of the cerebral hemisphere.

We have referred to the variability of the parieto-occipital fissure in the ape. In the anthropoid it is deep and strongly developed, but in the lower apes it is often extremely feeble; so much so, indeed, that it is not always an easy matter to distinguish it from neighbouring sulci. Often it fails to reach the mesial border of the hemisphere, and it is not an uncommon thing to see it doubled. This latter condition we have also observed occasionally occurring in the human brain.

In the chimpanzee the calcarine fissure cuts only to a very slight extent into the gyrus fornicatus. It is separated, therefore, from the hippocampal fissure by a superficial convolution. In the orang the calcarine fissure cuts the gyrus fornicatus more deeply than in man, but still a very manifest "isthmus" separates it from the hippocampal fissure. In many of the low apes the connexion between the two fissures at first sight appears to be complete. Indeed, Gratiolet described the calcarine and hippocampal fissures under one name, and regarded them in these

apes as forming one fissure. This is not the case, however. The connexion is only a superficial one, as the gyrus fornicatus is carried on in the form of a high, deep, annectant gyrus between them, and prevents their free communication. The whole question is one of degree. No communication of any kind occurs in the chimpanzee; a superficial connexion is established in the low apes, whereas in man and the orang an intermediate condition is seen.

VIII. **Development of the Parieto-occipital and Calcarine Fissures.**—The views which have been advanced by different authors regarding the origin of the parieto-occipital and calcarine fissures are very conflicting; and no doubt there are many points in connexion with their first appearance and history which are extremely puzzling.

v. Kölliker* maintains that they appear synchronous with the temporary fissures on the mesial aspect of the hemisphere, and constitute members of the same series, differing from them only in so far that they are permanent, and not evanescent. He says:—"As early as the separation of the frontal lobe from the temporal lobe by the Sylvian fossa there arises a boundary for the occipital lobe by the appearance of the parieto-occipital fissure. This is distinct in the third month. Schmidt even figures it in the eighth week."

Richter,† who gives a good account of the transitory furrows in a series of early embryos, appears to entertain the same view. Referring to a brain with hemispheres 3·3 cm. long, he remarks:—"An der medialen Seite der Hemisphären gingen einige radiäre Falten mehr von der Bogenfurche aus als bei Fötus 3. Bei letzerem zählte man im Verlauf der ganzen Bogenfurche fünf, bei Fötus 4 neun. Die Fiss. parieto-occ. und calc. standen bei Fötus 4 zur Bogenfurche ungefähr noch in demselben Verhältniss wie bei Fötus 3. Ausser der parieto-occ. und calc. verschwinden diese übrigen radiären Furchen der medialen Hemisphärenwände dieser Entwicklungsepoche sammt und sonders wieder und theilen so das Geschick der schon

* Entwicklungsgeschichte des Menschen und der höheren Thiere, 1879.

† "Ueber die Entstehung der Grosshirnwindungen," Virchow's Archiv, 1887, p. 398.

früher erwähnten occipitalen Falten früherer Stadien, obschon sie wie diese Totalfalten im His'schen Sinne sind."

Ecker* expresses himself on this question with considerable doubt and caution. "Moreover," he remarks, "it appears to me that one of the latter, viz. the fissura parieto-occipitalis is formed out of one of the temporary furrows, although I do not venture to assert this." This statement is rendered all the more ambiguous by the fact that in his description of the brain of a third-month fœtus he asserts that the occipital lobe does not exist. Undoubtedly the fissure in dispute (the precursor of the parieto-occipital) is present at this stage. Further, he figures the parieto-occipital and the calcarine fissures in a brain at the fourth month, although he appears to infer that they arise more frequently in the course of the fifth month.

According to Mihalkovics,† the calcarine fissure is the first to appear. It is formed at the end of the third month, and arises with the outgrowth of the occipital lobe almost simultaneously with the transitory furrows. The parieto-occipital sulcus is formed shortly after it at the commencement of the fourth month.

Having now stated the views of those authors who have dealt with this question, I shall proceed to state the conclusions at which I have arrived regarding the development of the parieto-occipital and calcarine fissures in the course of my study of the complete fissures.

At the same time, that the radial transitory fissures appear on the medial face of the hemisphere (towards the end of the second month or it may be at the beginning of the third month) two fissures which have a synchronous origin and lie in series with these, occupy positions which give them a close resemblance to the parieto-occipital and calcarine fissures of the fully developed brain. Between them is placed the primitive cuneus. I have never seen these fissures absent; and in all good illustrations of the medial face of the hemisphere at this stage of development (v. Kölliker, Richter, &c.) they are represented. We have already referred to

* "Zur Entwicklungsgeschichte der Furchen und Windungen der Grosshirnhemisphären im Fœtus des Menschen," Archiv für Anthrop., 1869.

† Entwicklungsgeschichte des Gehirns. Leipzig, 1887.

these infoldings as the precursors of the parieto-occipital and calcarine fissures.

One or other, or perhaps in some cases both, of these precursors may be retained in part or in whole, and ultimately enter into the formation of their respective fissure or fissures. Most frequently, however, one disappears, whilst the whole or a part of the other is retained. That which is obliterated is replaced later on (in the fifth month or in the beginning of the sixth month) by the permanent furrow; and this takes up very much the same ground as its forerunner, although it does not show an unbroken continuity of existence with it. I am satisfied that under no circumstances do both of the precursors entirely disappear again to be replaced by permanent successors. In the very large collection of fœtal brains which I possess, representing as they do every stage in the development of the cerebral surface from the third month upwards, there is not one in which there is not some part of this fissural system present.

The cerebral hemispheres which are represented in Plate III., figs. 3, 4, 5, and 6, afford us examples of the manner in which the precursor of the parieto-occipital fissure (*p. o.*) disappears, whilst the precursor of the calcarine fissure maintains its position. In these the parieto-occipital precursor is seen in various stages of obliteration. About the fifth month of intra-uterine life, therefore, it is not uncommon to find hemispheres in which the parieto-occipital fissure is totally absent, although the calcarine is present (fig. 15, Pl. I.). Sometimes, however, at this stage a faint trace of the parieto-occipital may be visible (figs. 4, 5, and 6, Pl. III., and fig. 16, Pl. I.). It is often hard to determine in these cases whether the faintly-marked parieto-occipital fissure is in course of obliteration or in process of formation. As a rule, a prominence on the inner surface of the ventricular wall corresponds with the weakly marked fissure, and this, taken in conjunction with the fact that, in the reappearance of the calcarine fissure in cases where a portion of its precursor has been obliterated, I have failed to detect such a projection, makes me incline to the view that the parieto-occipital in this instance is really in process of obliteration. His* has called attention to the fact that in certain fœtal brains of the

* Unsere Körperform, Neunter Brief, p. 114.

fifth month the calcarine fissure may exist alone on one hemisphere, whilst on the other the parieto-occipital is alone developed.

There cannot be a doubt that the precursor which most commonly becomes obliterated is the parieto-occipital. It is very questionable, as we shall see later, if the calcarine is ever obliterated from one end to the other. Its anterior end is preserved, and cases where the parieto-occipital precursor is seemingly alone retained are generally found to be in reality a conjunction of parieto-occipital with the retained portion of the calcarine. This is quite in keeping with the phylogenetic evidence we have on the question. In the ape there cannot be a doubt but that the calcarine is the more stable fissure of the two.

From what has been said the whole process of the development of these fissures will be seen to be subject to a considerable amount of variation. We shall, in the first instance, therefore, trace what appears to us to be the more common course of development, and then take note of the chief deviations from the normal process which we have observed.

At first, the precursors of the parieto-occipital and calcarine fissures are in direct connexion with the posterior fissura arcuata (*hintere Bogenfurche* of His) or hippocampal fissure (figs. 5 and 12, Pl. I.). During the course of the fourth month the gyrus fornicatus assumes shape, and as it gradually rises it cuts off the precursors from the hippocampal fissure. In the fifth month the hippocampal part of the gyrus fornicatus is very prominent, and interposes a very effectual barrier between the fissures in question.

The precursor of the calcarine fissure, after it is cut off from the hippocampal fissure, begins to shorten from its posterior end forwards (examine figs. 1 to 6 in Pl. III.) until there only remains a portion which represents about the anterior third of the original infolding. The posterior two-thirds are completely obliterated. The portion which is preserved forms the "stem" of the adult $-\!\!<$-shaped fissure, and alone assumes the responsibility of maintaining the intra-ventricular elevation which results in the calcar avis. In a considerable number of the figures in Plate III., this preserved portion of the calcarine fissure is to be seen. More particularly

is it evident in figs. 7, 10, 14, 15, and 17 (c'). In these the process which I have described may be observed at different stages.

The ground which was previously occupied by the portion of the calcarine precursor which has disappeared is afterwards taken up by another fissure—quite distinct and altogether different in its mode of origin. I refer to that part of the ≺-shaped fissural arrangement of the adult which I have named the *posterior calcarine sulcus*. This is very constant in its mode of origin, and is a *secondary sulcus* in every sense of the word. It follows the interrupted mode of fissural development. In other words, two punctiform depressions, or dimples, appear—one on the occipital pole, and the other midway between this and the hinder end of the anterior calcarine fissure or "stem" (Pl. I., fig. 26, c^2 and c^3; also Pl. III., figs. 14, 15, 17, 21, &c., c^2 and c^3). These deepen, and then show a tendency to run towards each other in the horizontal direction. The anterior depression extends more actively than the posterior one, and soon it approaches the "stem" in front, and its fellow-depression behind. The two small portions of cerebral surface which intervene between the three parts of the fissure represent the early condition of the two annectant gyri, which we have observed concealed within the adult calcarine fissure, viz. the gyrus cuneo-lingualis anterior and the gyrus cuneo-lingualis posterior. In the course of time the three parts of the calcarine fissure join over these intervening portions of cortex, which become pressed down into the bottom of the fissure. The union which first takes place is that between the intermediate piece and the stem; the junction between the intermediate piece and the hinder piece is of much later occurrence.

The time at which these two punctiform depressions appear to form the secondary posterior calcarine sulcus is very variable. In figs. 14 and 15, Pl. III., they are well seen in a brain midway between the fifth and sixth months. In figs. 12, 13, and 18, Pl. III., older specimens are exhibited in which not a trace of the developing sulcus is to be seen. Fig. 26, Pl. III., represents the inner surface of a fœtal brain close upon the seventh month, and yet on it the two punctiform depressions are merely seen in their initial stages; whilst in fig. 29 a brain is depicted very

little younger, in which the "stem" alone is present, and there are no signs of the posterior calcarine sulcus.

The union of the intermediate piece of the posterior calcarine sulcus with the "stem" or anterior calcarine fissure is represented in figs. 27 and 28, Pl. III. It usually occurs in the early part of the seventh month of intra-uterine life. In some cases, however, as we have noticed (2·3 per cent.), the connexion is never established, and the gyrus cuneo-lingualis anterior remains on the surface. The union of the two pieces of the posterior calcarine sulcus takes place at a period somewhat later. The hinder part forms little more than the forked extremity of the sulcus; and this is not as a rule joined on until the eighth or ninth month of intra-uterine life is reached. We have already noticed how extremely common it is in the last month of fœtal life to find the hinder end of the sulcus still separate, and the posterior cuneo-lingual gyrus on the surface. Indeed it is no rare thing to meet with this as a permanent condition. More especially is this the case in the negro brain. In half of the negro hemispheres which were examined it was present.

This interrupted mode of development of the posterior calcarine sulcus, viz. by isolated portions which ultimately run into each other, is very frequently observed in connexion with other permanent cortical furrows. Thus, the intra-parietal, præcentral, calloso-marginal sulci, the fissure of Rolando, and many others, afford examples. The posterior calcarine sulcus must therefore be included within the same category; and this relationship between the posterior calcarine sulcus and the fissures we have named is rendered all the more evident by the fact that in early stages of its development sections through the occipital lobe show that the depressions which represent the sulcus produce no corresponding elevations on the ventricular aspect of the hemisphere wall. *The posterior calcarine sulcus, therefore, is not a complete fissure, and from a developmental point of view it is quite distinct from the anterior calcarine fissure or "stem" which is a complete fissure, and, as a rule, shows an unbroken continuity of existence with the fore-part of the early calcarine precursor.*

In the ape, as we have already seen, the secondary posterior calcarine sulcus is apparently absolutely unrepresented. The calcarine fissure of the

ape is the equivalent of the "stem" or anterior calcarine fissure in man. In all probability it is preceded by a precursor with which it presents a direct continuity of existence. If this be the case this precursor does not diminish in length as in man. Its hinder end maintains its position near the posterior extremity of the hemisphere, or even turns round this as may be seen in some of the anthropoids.

In the development of the parieto-occipital fissure one or other of two courses may be followed. The precursor may be completely wiped out, and its place taken later on by a cortical sulcus which does not in any way impress the ventricular wall so as to produce an internal elevation, or it may be retained and modified so as to form the permanent fissure. In the latter, but not in the former case, the parieto-occipital must be included amongst the complete fissures.

An admirable example of the development of the parieto-occipital as a complete fissure is seen in the cerebrum depicted in figs. 28 and 29, Pl. I., This specimen was obtained from a fœtus which had probably reached the seventh month of development. In fig. 29 the fissure is exhibited as it is seen on the mesial aspect of the hemisphere. Its great depth is apparent. In fig. 28 the outer surface of the same brain is shown. The outer wall of the posterior ventricular cornu has been removed, and the intra-ventricular elevation corresponding to the parieto-occipital infolding is evident. This is so broad and conspicuous that it quite absorbs and appears to be continuous with the "stem" or anterior calcarine fissure; an examination of the bottom of the fissure from the opposite aspect, however, shows that they are distinct.

In contrast to this specimen examine that which is represented in figs. 27 and 30, Pl. I., and which is from a fœtus of about the same stage of development. Here the parieto-occipital is shallow, and produces no intra-ventricular elevation. In fig. 27, which gives a view of the interior of the posterior cornu of the ventricular cavity of the same brain, the bulging on the inner wall is seen to be of a totally different character from that in fig. 28. In other words, it is entirely calcarine in its origin.

But we have mentioned that even in cases where in the early cerebrum the parieto-occipital is a complete fissure, the bulging which it forms on the

ventricular wall is gradually obliterated as the hemisphere-wall thickens. In the adult brain the fissure reaches down to the ventricular cavity, and no further. The portion of the hemisphere in the adult with which it is in relation is solid, and not hollow.

The connexion which exists between the parieto-occipital and calcarine fissures in early times is a matter of importance. Many of the cases which have been described as instances of the presence of the parieto-occipital fissure in the early hemisphere and of the absence of the calcarine fissure are upon closer study seen to be capable of receiving a totally different interpretation. There are several hemispheres of this kind figured in Pl. III. (*vide* figs. 9, 12, 16, 26, &c.). Certainly on superficial inspection, the elongated fissure on the inner surface of the posterior part of the hemisphere appears in these cases to be the representative of the parieto-occipital, and of it alone. In most cases, however, a slight backwards projection placed a short distance below the mid-point of this fissure indicates that above this point we are dealing with parieto-occipital, and below this point with the anterior calcarine fissure, or the "stem." If the lips of the fissure be now opened up, a feeble interruption is seen at the bottom of the furrow immediately above the slight backwards projection. This is the primitive gyrus cunei, marking off thus early the parieto-occipital fissure from the "stem."

As a rule, however, there is no difficulty in recognizing the parieto-occipital fissure as a distinct furrow, and as one more or less separate from the "stem" or anterior calcarine fissure. In figs. 7, 8, 10, 13, 17, 21, 23, 29, &c., Pl. III., this is evident; and the distinction is more especially manifest in those cases in which the permanent parieto-occipital fissure is developed secondarily after the abolition of its precursor. Of course, in the event of the secondarily formed parieto-occipital fissure failing to unite with the "stem" or anterior calcarine fissure the gyrus cunei remains on the surface, as is usually the case in the anthropoid apes. In the adult human brain, however, we have seen that this is a very rare occurrence (3·9 per cent.).

The parieto-occipital fissure, in its upper part, at first assumes the form of a wide open furrow which extends upwards towards the mesial border of the hemisphere, and finally forms a broad notch upon it (Pl. III., figs. 28

and 29). This notch appears at a variable period, and is the earliest indication of the external parieto-occipital fissure. I have found it already well-marked in a hemisphere from a fœtus of about six and a-half months, but often it is well on in the seventh month before it is formed.

We have seen that in the adult and nearly mature fœtus a deep annectant gyrus frequently intervenes between the upper and lower parts of the parieto-occipital fissure. In the fœtus, although we remark that the lower part is narrow and fissure-like, and the upper part broad and open, we have no evidence that the fissure is developed in two pieces, and I have not been able to trace the manner in which the annectant gyrus intercuneatus is formed. Still in the adult we know that the fissure sometimes occurs in two pieces separated by this gyrus, which has risen to the surface. I have seen this condition once in the 128 hemispheres I have examined. Sernoff, of Moscow, has figured it. This would seem to indicate some tendency on the part of the parieto-occipital fissure to adopt the interrupted form of development.

I shall now proceed to take note of some variations in the development of the parieto-occipital and calcarine fissures which I have observed in the numerous specimens in my possession. Of course, as might be expected, great differences are seen in different hemispheres in the relative lengths of the "stem" or anterior calcarine fissure and the posterior calcarine sulcus. This, I take it, indicates that the extent to which the hinder end of the calcarine precursor is obliterated varies considerably within certain limits. But there are many cases in which the obliteration only proceeds to a very small extent, and then the greater length of the calcarine fissure is lineally descended from its precursor. This may be considered to be an approach to the condition present in the ape. It differs, however, in so far as that under no circumstances whatever is the posterior calcarine sulcus altogether absent, although it may in some cases be reduced to a small portion on the occipital pole, and be developed from a single punctiform depression.

But we occasionally meet with fœtal hemispheres in which we have a long deep fissure carried downwards from the upper margin of the hemisphere to the gyrus fornicatus (Pl. iii., figs. 18 and 19.) In such cases there may not be a trace of any separation into a parieto-occipital part proper,

and a "stem" or anterior calcarine fissure. Further we have seen that occasionally in the adult brain the cuneate gyrus is absent and the "stem" and the parieto-occipital are directly continuous. Are we to regard the "stem" in these exceptional cases as being formed by the parieto-occipital? Strong as the evidence is in favour of our adopting this view, I find it difficult to do so. I am inclined to believe that the stem is formed by the anterior part of the calcarine in every case, and that a very complete union of the precursors of the two fissures with an obliteration of the calcarine precursor up to the very point of junction is to be regarded as giving the true explanation of the exceptional cases I have quoted.*

Certainly upon phylogenetic grounds we might infer that the stem belongs solely to the calcarine fissure. In the anthropoid apes, as we have noted, the gyrus cunei is usually on the surface.

IX. **Topography of the Parieto-occipital fissure.**—I have endeavoured to determine the topography of the parieto-occipital fissure from two points of view—(1) in so far as this relates to its relative position on the mesial border of the cerebral hemisphere; and (2) in so far as it relates to its position with reference to the cranial wall.

In determining the position of the fissure on the upper border of the hemisphere, I have taken as the starting-point of my measurements the point at which it reaches this margin, and have therefore disregarded altogether the inclination of the external parieto-occipital fissure. Further, in those cases (and they are not few) in which the parieto-occipital fissure bifurcates before it reaches the cerebral margin, I have chosen neither of the terminal off-sets as the point to which I should measure, but have drawn an arbitrary line upward in the direction of the lower part of the fissure, and inserted a pin into the mantle-border at the point at which this line reaches it. This point I have taken as indicating the anterior limit of the occipital lobe on the upper margin of the hemisphere. The points between which I determine the mesial length of the upper border of the cerebrum I have already sufficiently defined in the introductory chapter of this Memoir. The different measurements which I have taken I have reduced to indices,

* I am aware that this statement is not altogether in keeping with the views I have previously expressed on this subject, but a more extensive study of the question, and a considerable increase in the number of specimens at my disposal, have caused me to alter my original opinion.—Journal Anat. Phys., vol. xxiv.

so that we can the more readily study the relative proportions of the different sections of the mesial border in brains of different sizes and at different stages of growth. This is readily done by supposing in every case the "mesial length" of the hemisphere to be equal to 100.

I have determined the point at which the parieto-occipital fissure reaches the upper border of the mantle—(1) in its relation to the occipital pole, and (2) in its relation to the upper extremity of the fissure of Rolando. By this means we obtain an *occipital index* which expresses the relative distance, along the upper border of the hemisphere, of the fissure from the occipital pole or, in other words, the mesial length of the occipital lobe; and a *parietal index* which expresses the distance at which, on the upper cerebral margin, the parieto-occipital fissure is placed behind the fissure of Rolando or, in other words, the mesial length of the parietal lobe. Being provided with these two indices a *frontal index* can be easily calculated; but the consideration of this we shall defer until we come to study the topography of the fissure of Rolando.

In the following table are placed the occipital and parietal indices which I have obtained for the human brain at its different periods of growth:—

THE HUMAN BRAIN.

Occipital and Parietal Indices—Mesial length of the Cerebrum along its Upper Border = 100.

Number of Hemispheres Examined.		Stage of Growth.	Occipital Index.	Parietal Index.
Intra-uterine life.	12	5½ to 6½ months,*. .	18·8	28·5
	12	6½ to 7½ months, . .	18·6	24·7
	20	7½ to 8½ months, . .	20·7	24·1
	24	Full-time fœtuses, .	20·8	25·7
Extra-uterine life.	12	First 12 months, . .	22·3	25·6
	14	4 to 5 years, . .	23·2	24·2
	6	11 to 15 years, . .	20·8	27·4
	82	Adults, . . .	21·2	25·5

* Of course, in these hemispheres the parieto-occipital fissure had not reached the mesial border, but by a line drawn upwards in the direction of the fissure the proper point on the margin of the hemisphere was obtained.

These indices are very instructive. They show that it is not until after birth that the occipital lobe attains its full development. During intra-uterine life it is shorter than it is at later stages in the growth of the brain. Broadly speaking from the fifth to the eighth month of fœtal life the occipital index may be said to be 18·8. From the eighth month to the full term of intra-uterine life the occipital lobe grows relatively at a rapid rate, and the occipital index of 20·8 is attained. The next stages in the growth-history of this lobe are peculiar, because it would appear that during the first five years of extra-uterine life it attains its maximum relative length, and presents finally an index of 23·2. It does not maintain this length, however, because as growth goes on, the occipital lobe becomes relatively shorter, until we obtain for the adult the index of 21·2.

Eberstaller* states that in 200 hemispheres he has measured the mesial border of the mantle, and calculated the relative position upon this of the parieto-occipital fissure. The relative distance of the fissure from the occipital pole with reference to the length of the cerebral border he reckons to be as 1 : 6. These figures, however, cannot be compared with mine, because Eberstaller measures the border of the hemisphere from the locus perforatus anticus in front to the occipital pole behind. My "mesial cerebral length" is obtained by measuring from the anterior end of the cerebrum in front to the occipital pole point behind.

In right and left hemispheres the occipital index is apparently the same. In forty-five right adult hemispheres the index was 21·2; in thirty-seven left adult hemispheres it was 21·3.

But there appears to be a sexual difference in this respect. In the female the occipital lobe is relatively longer than in the male. Forty-seven adult male hemispheres afforded an occipital index of 20·8; whilst 35 adult female hemispheres gave an average index of 21·7.

The parietal indices, expressing as they do the relative mesial length of the parietal lobe, also yield us some interesting information. We note that in the early fœtus ($5\frac{1}{2}$ to $6\frac{1}{2}$ months), this lobe is relatively long,

* Zur Oberflächen-Anatomie der Grosshirn-Hemisphären. (Vorläufige Mittheilung.) No. III. Wiener Medizinische Blätter, No. 19, 1884, p. 580.

the index being no less than 28·5. In the course of a month the proportion is reduced to 24·7; and the cause of this change is the rapid increase of the mesial part of the frontal lobe; the occipital lobe remains stationary in so far as its relative length is concerned. In the succeeding month, by an increase in the occipital lobe, the parietal mesial length is still further reduced, and now the index reaches its lowest point. In the new-born child we find that its normal proportion is attained, and this it maintains up to adult life. The fall in the index at the fourth and fifth year, and the sudden rise from the eleventh to the fifteenth year, are somewhat perplexing. The number of brains examined at the latter stage is hardly sufficient to enable us to draw decisive conclusions from the curious rise in the parietal index.

Let us now compare with the indices which are obtained for the human brain, those which are characteristic of the different forms of ape.

The Ape Brain.

Occipital and Parietal Indices—Mesial length of the Cerebral Hemisphere along its upper border = 100.

Number of Hemispheres examined.	Variety of Ape.	Occipital Index.	Parietal Index.
4	Orang, ...	23·2	21·3
4	Chimpanzee, ...	24·2	19·9
2	Hamadryas, ...	29·5	20·5
5	Cynocephalus, . . .	29·7	22·6
8	Mangaby, . . .	30·5	24·1
5	Macaque, ...	31	19
8	Cercopithecus, . . .	32·9	19
7	Cebus, ...	33·1	20·6

The low parietal index, and the high occipital index, are the leading peculiarities of the brain of the ape when examined from this point of view.

In regard to the relative length of the parietal lobe, measured along the mesial border, there is little difference between the high and low apes. Indeed in this respect it is not the anthropoid apes that stand nearest to man. The baboon and the mangaby show the highest parietal index, or, in other words, the greatest antero-posterior length of the parietal lobe. It is curious to note that it is the latter which exhibits the closest approximation to man.

But the study of the occipital indices will show that the reduction of the parietal indices is due to very different causes in the high and low apes. In the chimpanzee and orang the parietal lobe is reduced in mesial length, not so much by an increase in the occipital region as by a considerable increase in the mesial frontal region. The occipital length in the chimpanzee and orang is certainly greater than we find it in the adult human brain, but not much greater than in the child of four or five years old.

The low apes stand out in marked contrast with the high apes in this respect. The parietal length is reduced entirely by the greatly increased occipital length. The frontal length is also reduced as compared with that in man and the anthropoids. The mesial length of the occipital lobe is indeed remarkable, the index varying, as it does, from 29·5 to 33·1. It is interesting to observe that it reaches its maximum in the cebus.

As compared with the human brain, then, we learn the following points when we study the relative proportion of the different sections of the mesial upper border of the cerebral hemisphere:—

1. In both high and low apes there is a great reduction of the parietal portion of this border.

2. In the low apes there is an enormous increase in the length of the occipital portion of the border; whereas in the high apes, although there is likewise an increase of the corresponding part, this is of small amount.

3. The shortness of the parietal portion of the mesial border of the hemisphere in the high apes is due to the relative increase in the length of both the frontal and occipital sections of the border.

4. In the low apes the reduction of the parietal portion of the border is due entirely to the great size of the occipital lobe.

Gratiolet was well aware of the great distinction which exists between man and the apes in the relative length of the occipital lobes. He states that in man this lobe is "extremely reduced"; and he formulates the law that the more highly organized a member of the group is, the smaller is the relative size of the occipital lobes. The truth of this is at once seen by placing the occipital indices of the cynocephalus, orang, and man, in apposition with each other.

Occipital Indices.

Cynocephalus, 29·7. Orang, 23·2. Man, 21·2.

But quite as striking a difference between man and the ape is the small relative size of the parietal lobe in the latter. This is very evident to the eye in Plate viii., where we have several apes' heads depicted with the brains exposed *in situ*. It would be an interesting field for speculation to consider whether this parietal increase in the human brain has anything to do with the acquisition of the educated movements of the limbs—more especially of the upper limbs, and that wonderful harmony of action which exists between the brain and the hands, and which has played so important a part in the development of the species.

We must now study the relation which the parieto-occipital fissure at the point where it cuts the mesial border presents to the cranial wall. In entering upon this part of our investigation we must decide whether we are to examine the fissure in its relation to the lambdoid suture or to the lambda. The latter point or apex of the occipital bone lies in the mesial plane, whilst the fissure is placed at some distance to the outer side of this, Therefore, if we chose the lambda as our cranial point, it is necessary to draw a straight line outward from it at right angles to the mesial plane of the head, and note the position of the fissure with reference to this line. Notwithstanding the inconvenience of this proceeding there cannot be a doubt but that the lambda is the best point from which to make our measurements. At the same time I may mention that I strongly suspect that the discrepancies which characterize the results of many observers

who have sought to localize the position of the parieto-occipital fissure with reference to the cranial wall are largely due to the measurements having been made in some instances from the lambda, and at other times from the suture to the outer side of this.

Of course a considerable amount of difficulty is experienced in localizing in the fœtal head the position of the lambda, owing to the presence of the posterior fontanelle. We cannot judge this by the anterior end of the supra-occipital; it can only be done accurately by prolonging upwards on the two sides of the head the lines of the lambdoid sutures, and noting the point on the mesial line of the cranium where they intersect. This point I have taken as representing the lambda in the fœtal skull-capsule.

The results which I have obtained I shall express in indices, so that we may the more readily be able to detect the true relationships which exist between the fissure in question and the cranial wall at different periods of life. This index we may term the lambdo-parieto-occipital; and it is obtained by comparing the distance between the lambda and the fissure with the mesial length of the hemisphere reckoned as 100. The results which I have obtained are as follows :—

(I.) *Adults.*—Position of parieto-occipital fissure determined in 22 hemispheres; 14 male and 8 female; 13 right and 9 left.

Fissure in front of lambda, . . .	18 times; index 3·5.
Fissure coinciding with lambda (*i. e.* the point where it reaches the upper border of the hemisphere), . .	3 times (all male hemispheres, 1 left and 2 right).
Fissure behind the lambda, . . .	1 hemisphere; index 1·7 (male; left).

(II.) *Children,* 11 *to* 15 *years old.*—Position of parieto-occipital fissure determined 5 times; three times in the male; twice in the female; three times on the right side; and twice on the left side.

Fissure in front of the lambda, . .	3 times; index 2·5.
Fissure coinciding with lambda, . .	1 hemisphere (male, and right side).
Fissure behind the lambda, . .	1 hemisphere; index 2·8 (male, and left side).

(III.) *Children* 4 *to* 5 *years old.*—Position of the parieto-occipital fissure determined six times—in four males and two females; three times on the right side, and three times on the left side.

In every case the fissure was in front of the lambda. Average index 4·5.

(IV.) *First Year of Life.*—Position of the fissure determined six times—in one male, in five females; four times on the right side, and twice on the left side.

Fissure in front of lambda, . . .	5 times; index 5·7.
Fissure coinciding with lambda, . .	Once (female; left side).

(V.) *Full-time fœtuses.*—Position of the fissure determined nine times; in two females and seven males; six times on right side, three times on the left side.

Fissure in front of lambda in every case. Average index 4.

(VI.) *Fœtuses*, $7\frac{1}{2}$ *to* $8\frac{1}{2}$ *months.*—Position of fissure determined six times—in four males and two females, twice on right side and four times on left side.

Fissure in front of lambda in every case. Average index, 4·9.

(VII.) *Fœtuses from* $6\frac{1}{2}$ *to* $7\frac{1}{2}$ *months.*—Position of the fissure determined five times.

Fissure in front of lambda in every case. Average index 5·9 in front.

In the following Table I have given the average lambdo-parieto-occipital indices which have been obtained for the different periods of growth. In every case these indices indicate the relative distance of the fissure *in front* of the lambda, because, although individual cases are met with in which the fissure is placed behind this point on the cranial wall, and other cases in which it coincides with it, the general average always shows the fissure at a greater or less distance in front of the lambda. The number of hemispheres examined under each group is stated in the preceding list, and it is unnecessary therefore to repeat this item in the Table.

HUMAN BRAIN.

Lambdo-parieto-occipital Indices—Mesial length of the Hemisphere taken as 100—*The Indices express the relative distance of the fissure in front of the Lambda.*

Period of Growth.	Average Index for both Sexes and both Hemispheres.	Average Index for Males.	Average Index for Females.	Average Index for right side.	Average Index for left side.
Adults, ...	2·9	2·6	3·7	3·6	1·8
11 to 15 years, . . .	0·9	0·5	1·8	1·4	0·4
4 to 5 years	4·5	3·8	6·2	3·6	5·4
First year of life, . . .	4·8	8·7	4	5·2	4
Full-time fœtuses, . .	4	3·9	4·5	3·6	4·5
Fœtuses—7½ to 8½ months, .	4·9	5·5	3·8	4·8	5·1
Fœtuses—6½ to 7½ months, .	5·9	—	—	—	—

From these indices it is apparent that the relative position of the fissure with reference to the lambda is subject to a certain amount of variation. From the eighth month of fœtal life up to the fifth year of childhood the relation of the fissure to the lambda remains virtually the same. The index varies from 4 to 4·9. In fœtuses younger than this the distance between the lambda and the fissure is distinctly greater; and by examining the Table in page 57, in which the occipital indices are given, it will be seen that the reduction of the distance between the two points cannot altogether be explained by the changes which take place in the position of the fissure on the upper border of the hemisphere. It can only be accounted for by supposing likewise a slight forward movement of the lambda as the eighth month of intra-uterine life is approached. Again, from the eleventh year up to adult life, the distance between the lambda is very considerably reduced. In this case it would appear that the change is produced by a change in the position of the lambda, the fissure remaining more or less stationary. A study of the occipital indices will show that this explanation of the changing relations is

at least probable. But where we are dealing with two shifting points, as we are in this case, it is extremely difficult to apportion to each its proper amount of responsibility for the alterations which occur in their mutual relations. The difficulty is rendered in this case all the greater by the fact that the changes brought about are of a very slight character.

It would seem likely, although it is by no means conclusively proved, by the indices in the above Table, that the relative distance between the parieto-occipital fissure and the lambda is greater in the female than in the male. If this be the case it is quite in keeping with what we have learnt in regard to the female occipital index. We have noticed that this indicates a relatively greater length of the occipital lobe in the female cerebrum.

The position of the parieto-occipital fissure with reference to the lambda in the adult head has been very variously stated by different authorities. Sir William Turner* and Hare† place it in front of the lambda; Broca,‡ Bischoff,§ Hamy,|| and Hefftler¶ consider that, as a general rule, it coincides with this point in the cranial wall. Ecker, in one communication,** states that he found the median end of the fissure 7 mm. in front of the lambda, and, in another,†† states that the fissure corresponds tolerably accurately with the lambdoid suture. Féré,‡‡ who examined no less than

* "On the Relations of the Human Cerebrum to the Outer Surface of the Skull and Head," Journ. Anat. and Phys., vol. viii., p. 142. Also, "An Illustration of the Relations of the Convolutions of the Human Cerebrum to the Outer Surface of the Skull," Journ. Anat. and Phys., vol. viii., p. 359.

† "The Position of the Fissure of Rolando," Journ. Anat. and Phys., vol. xviii., p. 174.

‡ "Sur la Topographie cranio-cérébrale," Revue d'Anthropologie, 1876.

§ "Die Grosshirnwindungen des Menschen," Abhandl. der k. bayer. Akad. der Wiss., 11 Cl. x. Bd. 11 Abth.

|| "Contribution à l'étude du développement des lobes cérébraux des primates," Revue d'Anthropologie, 1872, p. 424.

¶ "Izviliny golovnavo mozga ou tchelovieka i otnochenia ich k'svodou tcherepa." Dissertation inaugurale chirurgicale à l'Acad. med. chir. de St. Petersburg, 1873.

** Archiv für Anthropologie, IX. 1876, p. 72.

†† Zur Kenntniss der Wirkung der Skoliopaedie des Schädels, &c. &c. Braunschweig, 1876, p. 22.

‡‡ "Note sur quelques points de la topographie cérébrale," Bull. Soc. Anat., 24 Dec., 1875 (Analyse faite par l'auteur lui-même).

sixty-two subjects, states that in thirty-nine it coincided with the lambda, in twenty-one subjects it was placed from 1 to 4 mm. in front of this point, whilst in two subjects it was placed from 2 to 3 mm. behind it.

The results which I obtained are therefore in accordance with those of Sir William Turner. In twenty-two adult subjects I only found the fissure once behind the lambda, and three times coinciding with it. In all the other cases it was placed in front, so that the average index for all the cases examined was 2·9 *in front*.

Foulhouze,* Hamy,† Féré,‡ and Symington§ have also studied the position of this fissure with reference to the cranial wall in the fœtus and child.

In children, Foulhouze in every case found the parieto-occipital fissure well in front of the lambda. The following is a brief summary of his results:—(1) In children one month old the distance of the fissure from the lambda was on an average 10·25 mm.; (2) in children four to five months old, 12 mm.; (3) in children eighteen months to three years old, 15·4 mm.; (4) in a child five years old, 19 mm.; (5) and in a child thirteen years old, 6 mm.

Hamy considers it to be a characteristic of the full-time fœtus to have the parieto-occipital fissure in front of the lambda. Féré examined a very large number of fœtuses and children. From the fifth month up to the end of intra-uterine life he gives figures which indicate that the fissure is placed from 8 to 12 mm. in front of the lambda; from birth up to the end of the first year, from 7 to 18 mm. in front of that point; and from the twenty-eighth month up to the twelfth year, from 0 mm. to 10 mm. in front of the lambda. Symington examined the fissure in its relations to the

* Recherches sur les Rapports Anatomiques du cerveau avec la voute du crane chez les enfants. Paris, 1876.

† "Contribution à l'étude du développement des lobes cérébraux des primates," Revue d'Anthropologie.

‡ Amongst a number of important papers published by Féré, we may specially mention, as bearing particularly on the present research, "Sur le développement du cerveau considéré dans ses rapports avec le crane," Revue d'Anthr., 1879. It is from this Paper that the figures quoted above are taken.

§ Topographical Anatomy of the Child. Edinburgh, 1887.

cranial wall in several children, and in all of them it was in front of the lambda. The distance varied from one-third of an inch to one inch.

The cranial relations of the parieto-occipital fissure in the ape are also of interest; and I subjoin a Table in which these are brought out by indices obtained in a manner similar to those already given for the human head. In Pl. VIII., also, drawings of the cerebrum in a macaque, baboon, cebus, orang, and chimpanzee, exposed *in situ*, are given.

Lambdo-parieto-occipital Index in the Ape.

Mesial length of the Cerebrum, 100. *The indices in every case indicate relative distance* in front *of the Lambda.*

Kind of Ape.	No. of specimens examined.	Index.
Chimpanzee, ...	2	5·5
Orang, ...	1	0 *
Cynocephalus, ...	1	8
Hamadryas, ...	1	13·2
Macaque, . . .	2	20·4
Cebus, ...	2	18·5

In one chimpanzee the fissure coincided exactly with the lambda; in the other it was 11 mm. in front of this point. The average index for the two was 5·5 in front of the lambda. In the orang the fissure and the lambda corresponded precisely with each other. Féré † has given us the results he has obtained on this matter in the heads of two young orangs. In both cases the fissure was behind the lambda—in one 7 mm. and in the other 5 mm. In the determination of this point he employed the French method of introducing pegs into the cerebrum through holes drilled in the cranial wall, and then removing the brain. To say the least of it, this is

* Fissure coincides with lambda.

† "Contribution à l'étude de la topographie cranio-cérébrale chez quelques singes," Journ. Anat. et Phys., vol. xviii.

an unsatisfactory plan, and the results obtained in this way cannot be accepted as being in every case absolutely accurate.

It will be seen, therefore, that the cranio-cerebral relations in the anthropoid apes, in so far as this fissure is concerned, are somewhat similar to those in man. Very different, however, are the corresponding relations in the lower apes. In all of these, with their large occipital lobes, the fissure, as is seen from the indices, lies well in front of the lambda. Very considerable differences in this respect are exhibited in different varieties of apes. In the baboon and hamadryas it will be seen that the relative distance between the two points in question is not so great as in the macaque and the cebus. Féré, in the Paper above referred to, gives us a great deal of information on the cranio-cerebral topography of the apes. He examined a large number of different varieties of apes, and in some cases as many as twelve specimens of one species. Unfortunately he only gives the absolute measurements, and these are, therefore of little value in the present research, where we are dealing entirely with relative results.

X. **External Perpendicular and External Calcarine Fissures.**—In his elaborate Memoir upon the convolutions of the human brain and their development in the fœtus, Bischoff* describes and figures a transitory fissure on the outer surface of the cerebral hemisphere under the name of "fissura perpendicularis externa." He states that it appears towards the end of the seventh month on the outer surface of the hemisphere, near its hinder end, in the form of a furrow, which runs downwards in a vertical direction. And then, further on (p. 449), he adds:—"But the fissure, which we have designated above the fissura perpendicularis externa, does not develop any further, . . . but disappears again in the course of the eighth month without taking any part in the formation of the later furrows on the occipital region." It belongs, therefore, he remarks, to that class of formations which only in certain forms (in the apes) attain their complete development, whilst in others they are arrested or completely disappear.

That such a fissure as a general rule exists on the fœtal human brain

* Abhandl. der k. bayer Akad. der Wiss., 11 Cl. x. Bd. 11 Abth., p. 448.

there cannot be a doubt (Pl. i., figs. 17 and 31; also Pl. ii., figs. 8, 9, 12, 17, &c., *e. p.*). Further it is a complete fissure, and is produced by a distinct infolding of the hemisphere wall. A corresponding elevation on the ventricular aspect of the mantle-wall is consequently present during the time that this fissure exists. It differs from the other complete fissures, which we have examined, in its late appearance. It never assumes form until all the other transitory fissures have disappeared. Ecker* has very rightly pointed out, however, that it is not between the seventh and eighth months of fœtal life that it is to be seen, as Bischoff has said, but much earlier. According to Ecker it appears in the fifth month. This authority further adds:—"That this furrow disappears at a later period is quite certain; for in the sixth and seventh month there is not a trace of a fissure in this position visible." Whilst I agree with Ecker as to the time at which the external perpendicular fissure appears, I consider that in most cases it has a longer duration than he is inclined to give it. I find it as a rule throughout the whole of the sixth month of development, although towards the end of this month it is clearly showing signs of commencing obliteration. It is rarely to be seen beyond the first week of the seventh month. Whilst this is the case, it must be admitted that the fissure in question is subject to a good deal of variation. Sometimes it appears to be entirely absent, whilst at other times its duration is cut short, and it has disappeared before the beginning of the sixth month.

There are many of the fœtal brains, which are figured in Pl. ii., which exhibit the fissura perpendicularis externa in various phases of its growth (*e. p.*). It will be noted that it is situated on the outer surface of the occipital lobe, and presents a direction similar to that of the parieto-occipital fissure on the medial face of the hemisphere. It is important to note, however, that it is placed in a plane which is distinctly behind that of the parieto-occipital fissure. It therefore occupies a position which corresponds exactly with that of the "Affenspalte" in the ape's brain, and I have little doubt that Bischoff is right in supposing it to be the

* "Zur Entwicklungsgeschichte der Furchen und Windungen der Grosshirnhemisphären im Fœtus des Menschen," Archiv f. Anthrop., Dritter Band, 3. und 4. Heft, 1869.

representative of the latter.* I have on a previous occasion † endeavoured to show that the sulcus transversus of Ecker cannot (in its entirety at least) be regarded as equivalent to the "Affenspalte," and this being assumed, the fact of the early disappearance of Bischoff's fissura perpendicularis externa cannot be quoted as evidence against its being the transitory representative in the human fœtus of the "Affenspalte." Lately I have obtained the brain of a newly-born male child (fig. 23) which shows a condition bearing very closely upon this question. The sulcus transversus of Ecker (S.T.) is present, but behind it there is another and larger transverse sulcus, which communicates below with the former, and which I am strongly inclined to believe represents a persistent condition of the fissura perpendicularis externa, or, in other words, of the "Affenspalte."

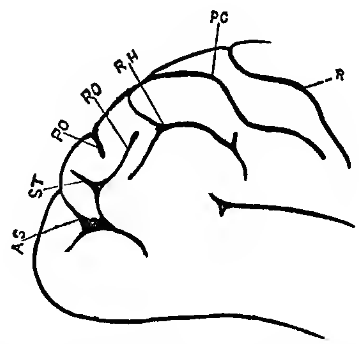


FIG. 23.—Right hemisphere of new-born child. R., fissure of Rolando; P.C., post-central sulcus; R.H., ramus horizontalis of the intraparietal fissure; R.O., ramus occipitalis; S.T. sulcus transversus occipitalis, of Ecker; A.S. "Affenspalte."

But in addition to all this it can be easily proved that the "Affenspalte" in the ape is *a complete fissure*. If the inner wall and hippocampus minor of the posterior horn of the lateral ventricle be carefully removed, so as to exhibit the deep surface of the outer wall, a smooth vertical elevation will be seen upon it which corresponds to the bottom of the "Affenspalte" (Pl. IV., fig. 2, *e*.).

* In a former paper upon the "Intraparietal Sulcus" (Journ. Anat. and Phys., Jan., 1890), I expressed a different opinion, but I am now satisfied that in this I was wrong.

† Journ. Anat. and Phys., Jan., 1890.

This is a most important point, because it not only shows that the fissura perpendicularis externa and the "Affenspalte" are similar in their mode of origin, and therefore in all probability homologous, but also that, if this fissure in man be transitory, as it undoubtedly is, the sulcus transversus occipitalis of Ecker cannot be regarded as the equivalent in the adult human brain of the "Affenspalte" in the ape's brain.

It is only in the brains of the low apes that I have proved the presence of an elevation on the outer wall of the ventricle corresponding to the bottom of the "Affenspalte." I cannot tell whether or not it exists in the anthropoid brain. Specimens of these are so valuable that I am unwilling to destroy those I have got, even in the determination of a point of this importance.*

For a time I considered the fissure which I have named the external calcarine as the same as the fissura perpendicularis externa, but its position and direction are such that I am now inclined (provisionally at least) to look upon it as a distinct fissure. It is placed very obliquely along the lower border of the occipital part of the cerebrum (Pl. I., fig. 14, &c., *e. c.*), and corresponds on the outer surface of the hemisphere with the calcarine fissure on the mesial face. When transverse sections are made through the occipital part of the cerebral hemisphere, the external calcarine fissure is seen to be a deep infolding of the hemisphere wall, and the bulging which it forms into the ventricular cavity lies exactly opposite, and may be actually in contact with the calcar avis (Pl. I., figs. 18 and 19).

The external calcarine fissure appears very early. It can be distinguished in a large number of cases amongst the primitive transitory furrows (Pl. I., figs. 3, 10, &c.), and at this period, as we have already noticed, it is sometimes continuous around the occipital pole of the hemisphere with the precursor of the true calcarine fissure. This connexion, where it exists, is always obliterated about the fourth month. In the human brain the external fissure is transitory. It is effaced towards

* The apes which I have specially examined with reference to this point are the Sooty Mangaby and the Cebus.

the end of the fifth month. It is not so constant as the external perpendicular fissure of Bischoff, and in many cases it fails completely.

Although evanescent in the brain of man, there is some reason to believe that it has a permanent representative in the brain of the ape. On the outer surface of the occipital lobe of most apes a deep fissure runs horizontally forwards from the occipital pole, and comes to an end a short distance behind the free anterior lip of the occipital operculum. This fissure is placed on the outer face of the hemisphere in an exactly corresponding position to the calcarine fissure on the mesial face, but it is shorter than the calcarine fissure; and its anterior end, in most of the numerous specimens I have examined, just falls short of the posterior horn of the lateral ventricle. In two species, however, both of which belong to the genus Cercopithecus, the fissure in question reached as far forward as the posterior part of the ventricular cavity, and formed a slight bulging on the outer ventricular wall opposite to the calcar avis on the inner wall (Pl. I., fig. 20). The second occipital sulcus in the human brain apparently corresponds with this fissure in the cerebrum of the ape—at least it corresponds to it in position, but not exactly in its history.

Eberstaller * gives this fissure in the adult brain a position of high importance. He terms it the "sulcus occipitalis lateralis," and considers that it should be held as forming, on the outer surface of the hemisphere, the inferior boundary of the occipital lobe.

Whilst in the description of these two transitory fissures on the outer aspect of the occipital lobe of the fœtal brain I have inclined to the view that they are to be regarded as distinct fissural integers, I am not blinded to the fact that it is very possible that we may really be dealing with one and the same fissure, which alters slightly in position according to variations in the growth-energy of this part of the cerebrum. It is certainly significant that, amongst the very numerous specimens which I possess, I have never seen the two fissures present on the same brain except in one instance, and as this was a specimen in which both fissures were almost completely obliterated, I do not consider that it offers us absolute proof on the

* Zur Oberflächen-Anatomie der Grosshirnhemisphären. (Vorläufige Mittheilung.) No. II.; Der Hinterhauptlappen. Wiener Medizinische Blätter, 1. Mai, 1884, No. 18.

question (Pl. II., fig. 17). A slight inequality on the surface of the cerebrum which has been produced artificially might readily be mistaken for a transitory furrow on the very verge of complete obliteration, and I am not satisfied that the external calcarine furrow in this case was not produced in this way. This is clearly a field for further investigation, because until we have undoubted evidence of the two fissures being present on the same hemisphere the question cannot be definitely settled.

Eberstaller * seems to doubt the transitory character of the external perpendicular sulcus. He says:—"Würde die Affenspalte des Menschen beim sechsmonatlichen Fötus vorhanden sein und im Laufe des achten Monates verschwinden (Bischoff), so würde diese Thatsache in Hinsicht auf die Ascendenz-Theorie eine weite Lücke zwischen dem Genus Homo und den Anthropoiden statuiren, denn je früher die Dauermerkmale einer inferioren Species in der embryonalen Entwicklung der höherstehenden Formen auftreten und je hinfälliger sie sind, umso weiter ab voneinander liegen beide Formen. Dass die Affenspalte nicht verschwindet, dass sie ein bleibendes Artenmerkmal des Menschen ist, welches in der vollendeten Entwicklungsform persistirt, dass sie überdies an weiblichen Gehirnen gewöhnlich einfacher ist wie an männlichen, restituirt den Menschen als unmittelbar an die Spitze der Anthropoiden gehörig und vermindert den zeitlichen Abstand."

In this Eberstaller is clearly in error. In the vast majority of cases, as we have seen, the fissura perpendicularis externa is undoubtedly obliterated. As we shall see also later on, the fissure, which in the adult human brain is generally regarded as the representative of the "Affenspalte," is really a dependency of the intra-parietal sulcus.

XI. **The Collateral Fissure.**—The question which must next be decided is one relating to the collateral fissure. Is this a complete fissure, and if so, when and in what manner is it developed? The collateral fissure is late of appearing. It is included by Pansch amongst the "Primärfurche," and therefore classified by him with the fissure of Rolando, the

* Zur Oberflächen-Anatomie der Grosshirnhemisphären. (Vorläufige Mittheilung.) No. III., Wiener Medizinische Blätter, 1884, No. 19.

præcentral, the intraparietal, and the parallel sulci. It is well on in the sixth month before it appears, and it usually first shows in the form of two or more shallow depressions, which ultimately run into each other. In some cases one of these pieces assumes a more or less transverse course, and is placed immediately below the end of the "stem" part of the parieto-calcarine fissure. This is an important part of the fissure, because it may produce on the floor of the ventricle an infolding, or elevation, which is the earliest form of the eminentia collateralis. It is only this central or middle part of the fissure which has any claim to the term "complete." The front and back portions of the sulcus, which ultimately join this part, present no corresponding ventricular elevations. (Pl. IV., fig. 4.) It is by no means uncommon for the lower end of the calcarine "stem" to be joined by a shallow intervening furrow with this transverse central part of the early collateral fissure. In several of the figures in Pl. III. a more or less intimate connexion of this kind is seen (figs. 19, 25, 26, 27, and 28). Further, in the left hemisphere of the male Fuegian figured and described by Seitz, a persistence of this early connexion between these two fissures was observed.*

In Pl. IV., figs. 3, *c.e.*, the elevation corresponding to the mid-collateral fissure in the floor of the ventricle is very evident, and it is seen to present a distinctly fold-like character.

At the same time it must be understood that in many brains no part of the early collateral fissure produces an elevation in the floor of the ventricle, and if the eminentia collateralis is formed at a later period, it is developed quite independently of the fissure. It appears to me that the connexion between the fissure and the ventricular elevation depends a good deal on the time at which the former appears. If the mid-part of the fissure developes early an infolding is produced; if late, there is no such result.

It is interesting to note that in all the specimens of the low apes which I have examined I have never seen the slightest trace of an eminentia collateralis. As is well-known, it is not an absolutely constant feature of the human brain.

* Zwei Feuerländer-Gehirne. Zeitschrift für Ethnologie, 1886.

The mid-part of the collateral fissure is thus occasionally a complete fissure, and in the same sense as the fissura perpendicularis externa. It may, like the latter, produce an infolding of the ventricular wall and an internal elevation. These differ from the other complete fissures, both transitory and permanent, in their time of origin. They do not appear until, at least, two months later, when the primitive transitory furrows have completely disappeared and the occipital lobe is thoroughly mapped out. It is questionable, therefore, whether we should put them in the same category as the others, because we can be by no means sure that after a lapse of two months the same causes which produce the primitive complete fissures are still operative. Still it should be noted that there appears to be a tendency at this period to surround the base of the occipital lobe by a circular infolding, the three different pieces of which are not in direct union. On the outside we have the fissura perpendicularis externa, on the inside the parieto-occipital, and on the under surface the transverse mid-collateral fissure. Further, as we have noticed, there appears to be a tendency for the parieto-occipital to run into the mid-collateral in the early stages of both, although this connexion is afterwards obliterated by the upheaval between them of the connecting piece of the gyrus lingualis and the hippocampal convolution. There cannot be a doubt but that the mid-collateral fissure, when present, belongs to this fissural system.

XII. **Summary.**—1. At an early period in the development of the cerebral hemispheres a series of deep infoldings of its thin walls make their appearance. On the exterior of the hemisphere these show in the form of sharply-cut linear fissures.

2. Certain of these fissures are permanent; the great majority are transitory.

3. The transitory fissures, with two exceptions, have disappeared by the time that the corpus callosum is fully formed.

4. A deficiency in the corpus callosum is associated with a persistence of the temporary fissures.

5. The temporary fissures indicate an important stage in the growth of

the cerebrum, and are apparently associated with the mapping-out of the occipital lobe.

6. A quadrupedal pause in the growth of the cranium brings the skull-capsule into antagonism with the growth of the hemispheres, and in consequence the wall of the cerebrum is thrown into folds. These folds disappear as the occipital lobe assumes shape, owing to the expansion of the cranial cavity, and a restoration of growth-harmony between the skull and brain.

7. Consequently it is only in Primates, which alone possess well-developed occipital lobes, that transitory infoldings of the cerebral wall in all probability exist.

8. The two transitory fissures which do not disappear before the full development of the corpus callosum are :—(*a*) the external calcarine, and (*b*) the external perpendicular fissure of Bischoff. In point of fact, the latter fissure does not appear until after the full development of the corpus callosum.

9. The external calcarine fissure produces an infolding of the outer wall of the posterior horn of the lateral ventricle, which presents the same direction, and lies immediately opposite to the true calcarine infolding, or calcar avis.

10. The fissure corresponding to this in the apes is, as a rule, permanent, and in some species its anterior end forms, in the adult, a bulging on the outer wall of the ventricle.

11. The external calcarine fissure disappears before the sixth month of fœtal life in man.

12. The external perpendicular fissure is present on the outer surface of the fœtal cerebrum from the beginning of the fifth month to the end of the sixth month.

13. It is a complete fissure and corresponds to the "Affenspalte" on the ape's brain.

14. The "Affenspalte" on the ape's brain is also a complete fissure, and presents a well-marked bulging on the outer wall of the posterior horn of the ventricle; but, unlike the external perpendicular fissure of the human fœtus, it is permanent.

15. Certain fissures, therefore, which are complete and temporary in the human brain are complete and permanent in the ape's brain.

16. The complete permanent fissures in the human brain are:—(*a*) the hinder part of the fissura arcuata; (*b*) the fore-part of the calcarine; (*c*) in many cases the parieto-occipital; and (*d*) in some cases the mid-collateral. The Sylvian fissure is not a complete fissure.

17. Of the fissura arcuata the hinder part alone is preserved as the fissura hippocampi. The fore-part, which is generally supposed to be retained as the callosal fissure, is in reality obliterated.

18. Synchronous with the appearance of the radial transitory fissures on the mesial face of the hemisphere two fissures appear, which lie in series with the former, and occupy the ground afterwards held by the parieto-occipital and calcarine fissures. They may be termed the precursors of these fissures.

19. The precursor of the parieto-occipital fissure sometimes shows an unbroken continuity of existence with the parieto-occipital fissure of the adult brain. In other cases it is obliterated, and its place is afterwards taken by a secondary sulcus, which attains, however, a very great depth.

20. In the adult brain the parieto-occipital fissure, even in its complete form, does not form any eminence on the inner wall of the posterior horn of the ventricle, because it does not extend downwards as far as the cavity. Above its lower end the hemisphere is solid.

21. The posterior part of the calcarine precursor is in every case obliterated, and the anterior part retained. The extent of the part obliterated varies considerably in different brains.

22. The anterior preserved portion of the calcarine fissure forms the "stem" of the —<-shaped fissural arrangement on this part of the hemisphere, and its hinder part corresponds to the calcar avis.

23. In the place of the hinder portion of the calcarine precursor, which is obliterated, a secondary furrow appears. This may be termed the posterior calcarine sulcus.

24. The posterior calcarine sulcus is formed in two pieces which run together, and also join the "stem." In this way the entire length of what, in ordinary anatomical language, is called the calcarine fissure is formed.

25. The posterior calcarine sulcus is not a complete fissure.

26. In the ape the entire length of the calcarine fissure is represented by that portion of the fissure which in man is termed the "stem," and by that alone. The posterior calcarine sulcus does not exist in any form in the apes.

27. The cuneus, therefore, has a different morphological value in the apes and in man. In connexion with this, see the abnormal human hemispheres figured in Pl. IV. (figs. 6 and 7). These exhibit certain conditions which approximate to those present in the ape.

28. The collateral fissure is usually developed in three portions—an occipital, an intermediate, and an anterior or temporal part. These ultimately run into each other, so as to form the continuous fissure. The occipital and temporal portions do not impress the ventricular aspect of the hemisphere wall. The middle portion, which may be termed the mid-collateral fissure, is at first placed transversely on the under surface of the hemisphere, between the occipital and temporal lobes. It, therefore, must be associated with the parieto-occipital and external perpendicular fissures, which occupy corresponding positions on the inner and outer aspect of the hemisphere. The mid-collateral fissure is often a complete fissure, and responsible for the production of the eminentia collateralis.

29. Taking the mesial length of the adult hemisphere to be 100, the occipital portion of the upper border is 21·2, and the parietal 25·5.

30. The occipital portion of the upper border of the hemisphere in the female is slightly longer than in the male in the proportion of 21·7 to 20·8.

31. In man, the occipital length is 21·2; in the orang, 23·2; and in the Cynocephalus, 29·7.

32. During the growth of the head the parieto-occipital fissure occupies a tolerably constant position, both on the surface of the cerebrum and with reference to the cranial wall. It is placed more in front of the lambda in the fœtus and child than in the adult.

CHAPTER II.

THE SYLVIAN FISSURE AND THE ISLAND OF REIL.

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I. **Development.**—The development of the Sylvian region of the cerebrum has engaged the attention of many anatomists. Reichert,* Ecker,† Pansch,‡ Mihalkovics,§ Broca,‖ as well as several others have studied the question with great care, and added greatly to our knowledge of this portion of the hemisphere surface. In reopening the matter I feel that I need make no excuse, because the very large number of specimens which

* Der Bau des menschlichen Gehirns. Leipzig, 1861.

† "Zur Entwicklungsgeschichte der Furchen und Windungen der Grosshirn-Hemisphären im Fœtus des Menschen," Archiv für Anthropologie, Dritter Band, 1869.

‡ "Ueber die typische Anordnung der Furchen und Windungen auf den Grosshirn-Hemisphären des Menschen und der Affen," Archiv für Anthropologie, Dritter Band, 1869.

§ Entwicklungsgeschichte des Gehirns. Leipzig, 1877.

‖ Revue d'Anthropologie, p. 663.

I possess (representing as they do every stage in the development of the region) have enabled me to clear up several points which have hitherto been somewhat obscure, and upon which also there has been some variance of opinion.

In the previous Chapter I have expressed the view that the Sylvian fissure cannot be regarded as forming one of the "Totalfalten," or complete fissures of His. The growth-projection into the cavity of the hemisphere which forms the corpus striatum and corresponds with the central lobe or insula on the surface is not produced by a folding in of the mantle-wall, but by an elevation in the floor of the prosencephalon. The surface area corresponding to this internal projection does not keep pace with the mantle, as the latter grows around it, and in consequence the Sylvian depression becomes evident.

As Mihalkovics has pointed out, it is towards the end of the second month of development that the first sign of the Sylvian depression may be detected. At the same time, it is right to state that its appearance is frequently delayed beyond this stage, and I have observed hemispheres well on in the third month with hardly a trace of it. We have previously noted that the Sylvian region at this period is not unfrequently the seat of a temporary fissure. As the fossa assumes shape, this fissure (when present) retreats before it, and seems to exercise little or no effect upon its development. In no instance have I ever observed a temporary fissure encroaching upon the Sylvian fossa when the latter has once become definitely mapped out, although one or more may approach so closely as to cut into its boundary wall (Pl. II., figs. 1 and 2).

At first the Sylvian depression exhibits a nearly circular outline, and lies on the outer face of the cerebrum immediately above the hilum of the bean-shaped hemisphere. The surrounding mantle is raised very slightly beyond the level of the surface of the fossa, so that the outline is by no means distinctly mapped out. As the fœtus enters upon the third month the depression usually becomes more apparent. The surrounding boundary of mantle-wall becomes higher and more evident, the area enlarges, and towards the end of this month it shows a tendency to elongate in the vertical direction, and at the same time take a backward inclination. In

the fourth month the elongation and backward bending of the fossa is more marked, and now the area is surrounded by a high projecting boundary of mantle-wall which limits it in the most definite manner. But soon another change in the outline becomes manifest. The simple arch-like form is lost. In the process of backward bending the anterior boundary is not affected equally throughout its whole length. Its upper two-thirds from this stage on alone participates in the bending, so that it tends to assume more and more

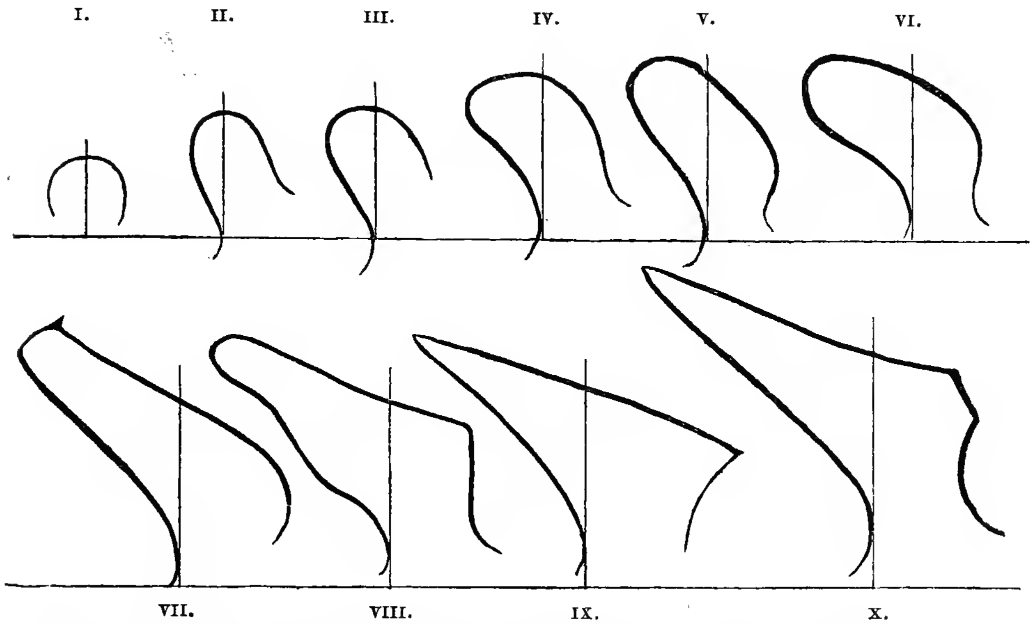


Fig. 24.—Diagram representing the different outlines assumed by the Sylvian depression in course of its development. Each outline has been taken from an actual specimen, and enlarged.

a horizontal inclination, while the lower third of this wall maintains its original direction, and descends in a more or less vertical direction. The two portions of the original anterior wall meet each other in a very wide open rounded-angle, and the outline of the Sylvian field becomes somewhat triangular. This change then is brought about by the elongation of the original anterior boundary wall, and the bending back of its upper two-thirds. About the beginning of the fifth month the triangular form of the

fossa is fairly established. It rarely occurs earlier, and frequently it is later in assuming this outline (fig. 24, I. to VII.; Pl. II., figs. 1 to 9).

From this stage on two different lines of development may be followed, and these lead to different results in the formation of the Sylvian fissure. In certain cases the anterior angle of the fossa becomes acute and sharp (fig. 24, VIII. and IX.; see also Pl. II., fig. 11), and the further history of such a condition of the bounding wall of the fossa is that, in all probability as the opercula are formed, a single anterior limb of the Sylvian fissure will appear. In the majority of cases, however, a different course is pursued. The anterior rounded angle becomes depressed and flattened, so that the superior more or less horizontal bounding wall is united to the anterior vertical boundary by a short intervening straight portion of varying length, which joins each of the other two portions at an angle (fig. 24, X.; see also Pl. I., fig. 24; and Pl. II., figs. 17, 20, 21, 24, &c.). The Sylvian fossa in such a case is therefore bounded below and behind by an oblique temporal wall—the original posterior wall of the fossa bent backwards and elongated. Above, it is limited by the posterior more or less horizontal portion of the original anterior boundary. This is formed by both the parietal and frontal lobes. In front we recognise two short portions, an oblique part on the outer face of the frontal lobe, and a vertical part on the orbital face of the frontal lobe. At this stage it must be remembered that the orbital surface of the frontal lobe is not so sharply marked off from the outer surface of the hemisphere as in the adult. These divisions of the bounding wall of the Sylvian fossa may be distinguished as the temporal, parieto-frontal, the frontal, and the orbital, and the further development of such a Sylvian region leads to the formation of two distinct anterior limbs of the Sylvian fissure, or perhaps to the Y condition of these limbs.

The change in the direction of the originally vertical Sylvian fossa is, no doubt, largely due to the backward growth of the entire hemisphere, and is associated with the appearance and mapping out of an occipital lobe. At the same time it must be remembered that the Sylvian area itself extends more rapidly than would be the case were its growth ordered by, and proportionate to, the general growth of the hemisphere surface. This is rendered very evident by measurement at different periods of its

development. Let us take as a standard the lateral length of the hemisphere, and equal to 100, and compare with this the length of the Sylvian fossa measured along its longest axis. The following Table gives the results of such an inquiry:—

Relative Length of the Sylvian Fossa (*i. e.* Insula or Central Lobe).

Lateral Length of the Cerebrum = 100.

Period of Development.	Number of Hemispheres Measured.	Fronto-central Index.	Central Index.	Occipito-central Index.
3½ months,	2	—	19·4	—
4½ to 5 months,	5	26·7	23·4	49·9
5 to 5½ months,	10	25·8	24·2	50
5½ to 6 months,	11	25·7	25·8	48·5
6 to 6½ months,	9	26·3	26·2	47·5
6½ to 7½ months,	3	26·2	28	45·8
7½ to 8½ months,	12	26·5	28·7	44·8

N.B.—In this Table the *central index* gives the relative length of the Sylvian fossa as compared with the lateral length of the hemisphere, which is taken as 100. The *fronto-central index* gives the relative length of the portion of hemisphere which lies in front, and *the occipito-central index* the relative length of the portion of hemisphere which lies behind the Sylvian fossa. It must be clearly understood, however, that the "lateral length" of the hemisphere referred to in this case is not the distance between the fore and hind points of the cerebrum measured in a straight line along the lateral surface of the cerebrum, but is the sum of three measurements—(1) the distance between the fore-point of the hemisphere and the foremost point of the fossa Sylvii; (2) the length of the fossa Sylvii measured between its two most distant points; and (3) the distance of the hindmost point of the fossa Sylvii from the occipital pole.

This Table brings out very clearly the steady growth of the Sylvian region from its first formation up to the end of intra-uterine life. In the third month it forms only 19·4 per cent. of the lateral length of the hemisphere; in the eighth month it is found to form 28·7 per cent. Its growth,

therefore, is not proportionate with that of the hemisphere : it is very much more rapid. But the figures in the Table further show that this excess of growth is altogether in a backward direction. The fronto-central and occipito-central indices prove this. Its anterior border retains very nearly the same position with reference to the anterior end of the cerebrum throughout, but its posterior end steadily approaches more and more nearly to the occipital pole. Thus the occipito-central index in the fourth month is 49·9, and in the eighth month, 44·8.

So much for the Sylvian fossa. We must next study the manner in which the area becomes covered in by the growth of the opercula. Each of the four subdivisions of the boundary wall acts as an independent line of growth. In the course of time, therefore, there are formed four distinct opercula, viz. a fronto-parietal (the operculum of Burdach), a temporal, a frontal, and an orbital. The temporal operculum, an offshoot from the subjacent temporal lobe, first becomes apparent (fig. 25, I., T.). In the first instance the growth affects only the anterior half of the temporal wall, but it gradually extends backwards to the posterior angle of the fossa. Before it reaches this, however, the fronto-parietal operculum becomes evident in the anterior two-thirds of this subdivision of the bounding wall (fig. 25, I., F.P.), and it gradually extends backwards to meet the posterior part of the temporal operculum at the posterior angle of the fossa. These changes occur in the latter half of the fifth month. As the temporal operculum creeps upwards over the lower part of the floor of the fossa, and the fronto-parietal operculum grows downwards over the upper part of the area, it becomes apparent that the growth energy of the former is more intense than that of the latter. It therefore follows that when the two opercula meet in the sixth month, and close in the posterior part of the space, there is more of the Sylvian area covered by the temporal than by the parieto-frontal operculum. During this time there is no appearance of either the frontal or the orbital operculum. The portions of the bounding wall from which these proceed are becoming more salient and projecting, but it is not until the temporal and parieto-frontal opercula have met over rather more than the posterior half of the fossa that they begin to show signs of active growth. This stage is reached about the

end of the sixth month. The frontal operculum grows downwards and backwards, and forms a small wedge-shaped mass with its apex directed towards the temporal operculum (fig. 25, II., F.). It forms that portion of the inferior frontal convolution which has been termed by Broca* the "cap," and by Eberstaller,† Zuckerkandl,‡ and others, "the pars triangularis" (Pl. II., figs. 17, 19, 20, &c., F.). The orbital operculum grows

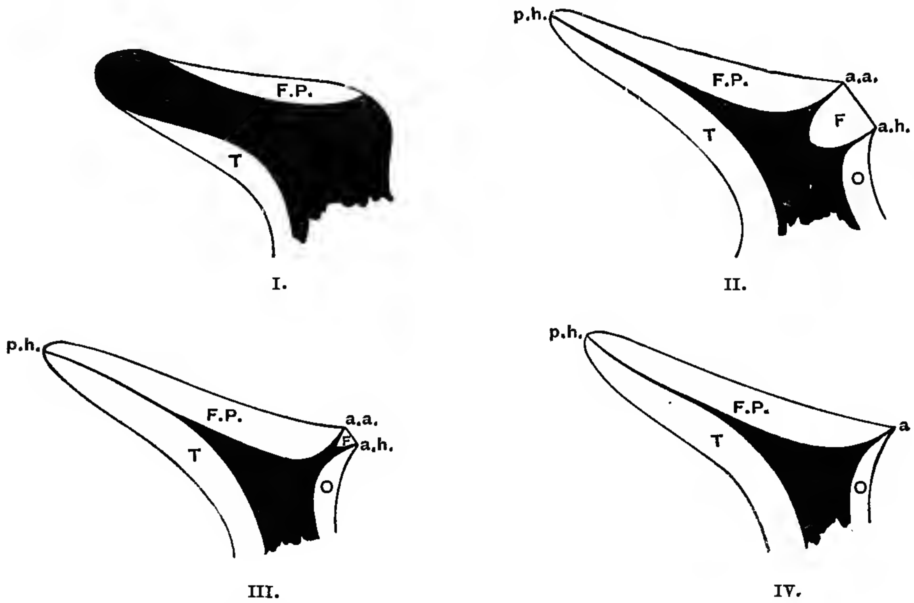


FIG. 25.—Diagrams illustrating the manner in which the Insular Region is covered in by the various opercula. The part printed black represents the uncovered part of the area; the light, unshaded portions represent the different opercula. *F.P.*, fronto-parietal operculum; *T.*, temporal operculum; *F.*, frontal operculum; *O.*, orbital operculum; *p. h.*, posterior horizontal limb of the Sylvian fissure; *a. a.*, anterior ascending limb; *a. h.*, anterior horizontal limb.

directly backwards, and in the fully-formed brain comes to lie in great part under cover of the anterior projecting extremity of the temporal lobe (Pl. I., fig. 33 *o.*; Pl. II., figs. 17, 20, and 24 *o.*). Towards the end of the

* "Sur la Nomenclature Cérébrale," Bulletin de la Société d'Anthropologie, 2e Série, t. XII., 1877, p. 614.

† Das Stirnhirn. Wien und Leipzig, 1890, p. 105.

‡ "Ueber den Einfluss des Nahtwachsthumes und der Schädelform auf die Richtung der Gehirnwindungen," Medizinische Jahrbücher, 1883, III. and IV. Heft., p. 449.

sixth month the first transverse convolution of Heschl appears on the deep surface of the back part of the temporal operculum. (Pl. II., figs. 20, 21, and 24 *h*.)

The four opercula of the Sylvian region are in their fully developed condition separated from each other by the three limbs of the Sylvian fissure which appear on the outer face of the hemisphere. In other words, these limbs of the fissure are formed by the meeting of the margins of the different opercula. The *posterior horizontal limb* intervenes between the temporal and fronto-parietal opercula; the *anterior ascending limb* separates the contiguous margins of the fronto-parietal and the frontal opercula; whilst the *anterior horizontal limb* intervenes between the frontal (pars triangularis) and the orbital opercula.

As is well known the complete enclosure of the insula is not affected until the end of the first month of infantile life, although I have met with cases in which it has been delayed until the third month of infancy.

Of all the four opercula the frontal, or pars triangularis, is the one which is subject to the greatest variations in growth energy. Many instances occur in which its apex fails to meet the temporal operculum, and in these cases the margins of the orbital and fronto-parietal sections meet below it, and form a common stem, from the summit of which the shortened anterior ascending and anterior horizontal limbs of the Sylvian fissure proceed. This is the well-known Y condition of the anterior limbs of the fissure (fig. 25, III.).

Should the fronto-parietal and the orbital opercula fail to meet below the stunted pars triangularis an open condition of the Sylvian fossa results. A well-marked example of this is seen in Pl. VIII., fig. 16, in the brain of an old man aged 70. The space which should be occupied by the frontal operculum, or pars triangularis, is vacant, and the corresponding portion of the insula is exposed.

There appears to be a wide-spread impression amongst anatomists (in America, especially), that the exposure of a portion of the island of Reil in the adult brain is a mark of inferiority. Dr. Charles K. Mills* quotes a

* Presidential address delivered at the Meeting of the American Neurological Association, in June, 1886.—Journal of Mental and Nervous Diseases, New York, September and October, 1886, vol. xxxiii.

number of cases of this kind which he had observed in lunatics, criminals, and in negroes. I am so fortunate as to possess twelve cerebral hemispheres of negroes, which were presented to me by the late Dr. W. Hart, of Sierra Leone. In only one of these is there any exposure of the island of Reil, and this to a very small degree. On the other hand, the pars triangularis is in the great majority particularly well developed, and in no respect different from the condition in which it is found in the European. In the orbital operculum, however, there is a manifest deficiency. Not only does this fail to extend so far inwards upon the orbital face of the frontal lobe, as in the case of the European, but it also appears to be shorter.

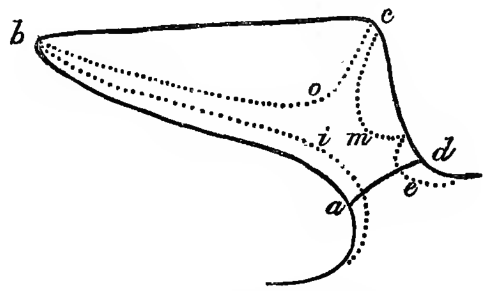
I quite agree, therefore, with the following remarks on this subject, which have been made by Rudinger*: "Ob dieses Offensein der Fossa Sylvii zur Zeit der Geburt eine bleibende Anordnung bei niederen Racen ist, muss so lange als offene Frage betrachtet werden, bis eine grössere Anzahl Gehirne von niederen Racen unversehrt der Untersuchung zugänglich sein wird. In Alkohol konservirten Präparaten an welchen die Pia mater entfernt wurde können über diesen Punkt nur ungenügenden Aufschluss geben."

The foregoing account may be regarded as giving the more usual course which is followed in the development of the opercula which close in the Sylvian fossa, but I have referred to cases in which, towards the end of the fifth month, the originally rounded anterior angle of the open fossa becomes acute and pointed (Pl. II., fig. 11). When this occurs, the usual course is that development goes on without the formation of a frontal operculum. The temporal, fronto-parietal, and the orbital opercula alone appear, and only one anterior limb of the Sylvian fissure is formed. This is interposed between the contiguous margins of the fronto-parietal and the orbital opercula (fig. 25, IV.).

Broca has given a diagram of the development of the Sylvian opercula which I take the liberty of reproducing (fig. 26). It differs in several essential points from mine. He shows a retention of the primitive anterior angle of the fossa (*c*), and yet he indicates the development, not only of a

* "Zur Anatomie des Sprachcentrums." Stuttgart, 1882, p. 5.

pars triangularis, but also of two anterior limbs of the Sylvian fissure. As we have seen, however, in those cases where the primitive anterior angle of the fossa is retained and becomes acute, there is no pars triangularis formed, and only one anterior limb of the fissure is developed. This limb is distinct from both the anterior ascending and the anterior horizontal limbs. It is homologous with neither, but in its lower part corresponds with the stem of the Y when the parieto-frontal and the orbital opercula meet below the pars triangularis. Every gradation is met with between this Y condition



o., . . . fronto-parietal operculum.
m., . . . frontal operculum.
i., . . . temporal operculum.
e., . . . orbital operculum.
b., . . . posterior horizontal limb of Sylvian fissure.
c., . . . anterior ascending limb.

Fig. 26.—Broca's diagram of the development of the Sylvian opercula.

of the anterior limbs of the Sylvian fissure and the single anterior limb. The latter may be considered to represent a fusion of the two others; but as we have said, it is not strictly homologous with either, although, according to the inclination which it assumes, it is frequently, and in the most arbitrary manner designated, "ascending," or "horizontal," as the case may be. The inclination of the single anterior limb, as well as of the two anterior limbs, when they are present, is determined by the relative development of the opercula between which they intervene.

II. **Anterior Limbs of the Sylvian Fissure in the Adult Brain.**—It is very necessary that we should establish clearly the conditions by which we can recognize "an anterior limb" of the Sylvian fissure. Some confusion has arisen from the fact that different authors have had different ideas as to the characters by which an "anterior limb" should be judged. Very few have condescended to give a sufficiently precise definition.

Pansch* considers it a requisite that the anterior limb should cut right through the operculum. Giacomini † and Eberstaller ‡ add a still further requirement, viz. that the incision in the operculum should be so complete that it should reach the furrow surrounding the island of Reil. We hold to the latter definition, but would add two further essentials, viz.—(1) that it is a necessary character of an "anterior limb," that it be a primitive deficiency in the opercular covering of the fossa of Silvius, and not a cleft subsequently developed; and (2) that it should lie in front of the inferior præcentral or prærolandic sulcus. With reference to this last requirement we may remark that Broca has very properly pointed out the important relations which the "anterior limbs" present to the inferior frontal convolution. In fact he states that they are the result of the great development acquired by this convolution. If we regard, therefore, an offshoot of the Sylvian fissure which cuts into the base of the anterior central convolution an "anterior limb," we strip it of one of its most pronounced characters. But this last part of the definition which we have advanced only comes into play in our determination of what is, and what is not, an "anterior limb" in the anthropoid ape. In all probability it would not be necessary were we familiar with the development of the hemisphere surface in the ape, because an "anterior limb" placed behind the inferior præcentral sulcus is not likely to be developed as a primitive deficiency in the operculum.

Broca § has undoubtedly the credit of having first accurately enunciated the fact that we must recognize two anterior limbs of the Sylvian fissure, viz. an anterior ascending and an anterior horizontal. He is wrong, however, in so far as he insists upon their being absolutely constant in the human brain, except in the case of imbeciles, idiots, and microcephalic individuals. It is true that he subsequently modified this statement to a a slight degree. Thus, in the same periodical, in 1883, he writes: "The

* "Ueber die typische Anordnung der Furchen und Windungen," &c. &c., Archiv für Anthrop., Dritter Band, p. 235, 1869.

† Varietà della circonvoluzioni cerebrali dell' uomo. Torino, 1882.

‡ Das Stirnhirn, p. 17. Wien und Leipzig, 1890.

§ "Etude sur le cerveau du gorille," Revue d'Anthrop., 1878, 2e. Série, p. 1.

cases where the two anterior limbs fail can be considered as abnormal, for they are quite exceptional, and they are observed for the most part (not all, however) in the brains of imbeciles, idiots, or microcephalic individuals."

Previous to this, however, both Pansch and Bischoff had mentioned that there might be more anterior limbs of the Sylvian fissure than one. The former author* remarks: "Auf diese Weise wird man ausserdem öfters noch eine zweite kleinere, ebenfalls den ganzen Mantelrand durchsetzende Furche finden: die früher schon erwähnte, als Ramus ant. f. S. bezeichnete Furche (bei jedem vierten Hirn)." Still it is perfectly clear from his figures that he did not recognize the two limbs which have been so clearly described by Broca. Thus, in Plate v., fig. 11 of his work he represents both the limbs very distinctly in a fœtal brain, but he calls the anterior horizontal limb the "ascending," and the other he names the first radial "Primärfurche," or præcentral sulcus.

Bischoff is equally vague on this point. In his great work upon the convolutions of the human brain he alludes to only one anterior limb, which he terms the "anterior or perpendicular ascending limb,"† whilst in certain of his figures he represents two (*vide* his figures 7 and 11). In the latter case it is the ascending limb which he fixes upon as the single anterior limb, whilst the other he leaves unlettered. But that he was aware that there might be more than one limb is evident from the following passage which appears in his description of the brain of a gorilla:‡ "Der vordere kürzere Schenkel der Spalte ist bei dem Menschen immer in mehrere, wenigstens zwei, aber auch drei und selbst vier Zweige zerlegt, um welche sich die Windungen der dritten oder unteren Stirnwindung in Bogen herumziehen."

* "Ueber die typische Anordnung der Furchen und Windungen, &c., Archiv f. Anthrop., Dritter Band, p. 235, 1869.

† "Die Grosshirnwindungen des Menschen," &c., Abh. d. 11. Cl. d. k. bayer. Ak. d. Wiss. x. Bd., 11. Abth., p. 428.

‡ "Ueber das Gehirn eines Gorilla und die untere oder dritte Stirnwindung der Affen," Sitzung der math.-phys. Classe vom 10. März, 1877, k. Akademie der Wissenschaften, München.

Ecker* also only recognizes one anterior limb, the ascending, and although he figures the development of both, he does not refer to the anterior horizontal limb (*vide* his fig. 3, Pl. iv.).

Hervé† repeats in every particular the description of Broca, and lays stress upon Broca's statement that one of the two limbs, viz. the anterior horizontal, is constant and essential, whilst the other, the ascending, is only accessory. As we have seen, the development of the region does not bear out this view, because when one limb only is present, it is neither the ascending nor the anterior horizontal, but a compound of both. It is upon the condition of the Sylvian fissure in the orang and chimpanzee that these authors found their opinion as to the predominant importance of the anterior horizontal limb. It will be our duty later on to show that the arrangement in these apes can bear another interpretation.

Zuckerkandl‡ has examined the two anterior limbs of the Sylvian fissure in a series of fifty hemispheres, but the conclusions which he draws from these are hardly justified by the facts, because he includes in the list fissures which did not completely cut through the operculum, and further, he appears to take for granted, as Broca also did, that when one anterior limb alone is present, this is the anterior horizontal limb. The following is a summary of his results:—

Ascending limb.—(*a*) In twenty-nine cases it cut right through the operculum; (*b*) in twenty-one cases it only cut partially into the operculum.§

Anterior horizontal limb—(*a*) In thirty-six cases it was normal; by this, I presume, he means that it penetrated right through the operculum; (*b*) in fourteen cases it was absent or represented by a mere notch.

* "Zur Entwicklungsgeschichte d. Furchen u. Windungen d. Grosshirn-Hemisphären," Archiv f. Anthrop., Dritter Band, 1869.

† La circonvolution de Broca. Paris, 1888.

‡ "Beiträge zur Anatomie des menschlichen Körpers," Ueber den Einfluss des Nahtwachsthumes und der Schädelform auf die Richtung der Gehirnwindungen.—Medizinische Jahrbücher, 1883, iii. und iv. Heft., p. 446.

§ When studying the development of the anterior limbs of the Sylvian fissure I frequently

Zuckerkandl, therefore, concludes that the anterior horizontal limb is more inconstant than the ascending limb. In this respect his views are in accordance with those of Giacomini.* For my own part the only inference which I can draw from these figures of Zuckerkandl is that the combination of the two limbs appears to be a more common condition than the presence of a single limb.

Eberstaller† entertains a very just conception of the relationships which exist between the anterior limbs of the Sylvian fissure. He points out that we may find all possible gradations between the single anterior limb, which he indicates by the letter I; to the Y, to the V, and to the U conditions. Under such circumstances he very properly considers it superfluous to argue which is the more constant of the two limbs. The two branches are merely the product of the differentiation of the single branch, and are brought into existence by the growing downwards, into the single limb, of the pars triangularis—a part of the strongly-developed inferior frontal convolution. He further states that in 45 per cent. of the hemispheres he examined he found the two anterior limbs completely separated from each other; whilst in 24 per cent. he found the single anterior limb alone present.

Three different conditions, then, of the anterior limbs of the Sylvian fissure may be recognized:—

1. A single anterior limb.
2. Two entirely separate limbs, viz. an ascending and a horizontal.
3. Two limbs (ascending and horizontal) opening into the Sylvian fissure by a common stem. This may be distinguished as the Y-shaped condition.

observed in the brain of the eighth-month fœtus, in cases where the true ascending limb was absent, a superficial furrow developing in its place. The same sulcus can frequently be seen in the adult brain; but in so far as it does not represent a primitive deficiency in the operculum it cannot be considered as a true ascending limb. It is the sulcus diagonalis of Eberstaller.

* Varietà della circonvoluzioni cerebrali dell' uomo. Torino, 1882.

† Das Stirnhirn. Wien und Leipzig, 1890, p. 19.

Single Anterior Limb.—We have already stated the manner in which this limb is developed, and insisted upon its being regarded as quite distinct from the anterior horizontal limb with which it has been frequently confounded. It is invariably placed on the outer face of the hemisphere. I have never seen it on the orbital face of the frontal lobe. As a rule it lies somewhat above the lower margin of the cerebrum, and it presents a very variable inclination—sometimes more or less horizontal, at other times it is distinctly ascending.

In eighty hemispheres it was found twenty-four times, or, in other words, in 30 per cent. This is a somewhat higher percentage for this condition than that which was obtained by Eberstaller.

Two Anterior Entirely Separated Limbs.—The anterior ascending, and the anterior horizontal limbs when distinct, as Broca and Eberstaller have pointed out, may issue from the stem of the Sylvian fissure, so close together, that together they form a V-shaped figure, or they may be slightly separated at their origin, and then they give rise to a U-shaped figure. They diverge with very varying degrees of obliquity. The ascending limb, in rare cases, is vertical, but much more frequently it takes an oblique upward and forward course. The usual direction of the horizontal limb is one straight forwards immediately above the margin which separates the outer from the orbital face of the frontal lobe. In this case both limbs appear on the outer surface of the hemisphere. But very frequently the anterior horizontal limb is distinctly on the orbital face of the frontal lobe, and cannot be seen when the cerebrum is viewed in profile. In such cases it must be borne in mind that no fissure on the under aspect of the hemisphere can be considered the anterior horizontal limb of the fissure of Sylvius unless it lies to the outer side of the external orbital sulcus. The so-called fourth anterior limb of the Sylvian fissure which, when it exists, is placed on the inner side of the external orbital sulcus, is very apt to be mistaken for the anterior horizontal limb.

In thirty hemispheres out of the eighty, in which the two anterior limbs of Sylvius were quite distinct and separate from each other (*i. e.* in 37·5 per cent.), the anterior horizontal limb was placed on the orbital face of the frontal lobe in twelve (*i. e.* 40 per cent.), and on the external face in

eighteen (*i. e.* 60 per cent.). If we analyze these thirty cases, we find the following results:—

—	Right Side.	Left Side.	Male.	Female.
Anterior horizontal limb on the orbital face of the frontal lobe 12 times, ...	80 per cent.	20 per cent.	60 per cent.	40 per cent.
Anterior horizontal limb on the outer face of the hemisphere, 18 times, . .	24 ,,	76 ,,	50 ,,	50 ,,

From this it would appear that the orbital position of the anterior horizontal limb is more common on the right hemisphere than on the left.

The Y-*shaped Condition of the Anterior Limbs.*—As Eberstaller has so well shown, this condition by the shortening or the lengthening of the common stem exhibits every gradation between the V form of the two separate limbs and the single anterior limb. It was noted twenty-six times in the eighty hemispheres examined, *i. e.* in 32·5 per cent.

The following Table gives the relative frequency of the three conditions in which the anterior limbs may exist according to sex and side:—

Relative frequency according to Sex and Side of the three conditions of the Anterior Limbs of the Sylvian Fissure.

Eighty hemispheres examined, viz. 52 *male,* 28 *female;* 46 *right,* 34 *left;* 64 *adult,* 16 *children.*

Condition.	Right.	Left.	Male.	Female.	Total.
Single anterior limb, . .	(19 times) 41·3 p. c.	(5 times) 14·7 p. c.	(16 times) 30·8 p. c.	(8 times) 28·5 p. c.	(24 times) 30 p. c.
Two separate limbs, . .	(15 times) 32·6 p. c.	(15 times) 44·1 p. c.	(21 times) 40·4 p. c.	(9 times) 32·1 p. c.	(30 times) 37·5 p. c.
Y-shaped condition, . .	(12 times) 26·1 p. c.	(14 times) 41·1 p. c.	(15 times) 28·8 p. c.	(11 times) 39·3 p. c.	(26 times) 32·5 p. c.

Some very interesting points are indicated in this Table. The most common condition is clearly that in which the two limbs are distinct and separate. Further, it is important to note that this condition is more frequently present in the male, and on the left side, than it is in the female, and on the right side. Whether this has any significance in connexion with the development of the motor centre of speech, which is placed in the pars basilaris, or that portion of the lower frontal convolution which is situated between the præcentral sulcus and the anterior ascending limb of the Sylvian fissure, it is impossible to determine at present. Next in point of frequency comes the Y condition of the anterior limbs, and this is peculiar in being more common on the left side, and in the female. Lastly, the remarkable point about the single anterior limb is its marked preference for the right side. It, apparently, occurs with nearly equal frequency in the two sexes.

III. **The Orbital Limbs of the Sylvian Fissure.**—In certain cases the orbital operculum of the island of Reil will be found to be cut into by one or two fissures which cut through its entire thickness, and extend straight forwards for a short distance on the orbital face of the frontal lobe. These are distinguished from the true anterior horizontal limb in so far that they both lie to the inner side of the posterior end of the external orbital sulcus. They may be termed the external and internal orbital limbs of the Sylvian fissure. The external is much more frequently present, and is longer than the internal. It cuts the orbital operculum immediately to the inner side of the posterior extremity of the external orbital sulcus, and its length varies from a few millimetres up to 1 cm. The internal orbital limb is much shorter as a rule, and is often little more than a notch. When present it may be looked upon as the anterior branch of a terminal bifurcation of the furrow, which bounds the island of Reil anteriorly, and it therefore gives to the orbital operculum a short free internal border which it does not possess when this little fissure is absent.

These little incisions into the orbital operculum were first observed and described by Benedikt.* He says: "Als Typus der äusseren Orbitalfurche

* Anatomische Studien an Verbrecher-Gehirnen. Wien, 1879, Epilogomena I., p. 107.

scheint aber folgendes Verhältniss zu bestehen. Unter dem untersten Rande des M der Stirnwindung besteht eine kurze (dritte) Incision der sylvischen Spalte als hinterstes Stück der äusseren Orbitfurche. Dieses Stück fehlt oft ganz, oder ist nur durch einen leichten Eindruck angedeutet." He further states that this fissure may communicate with the external orbital furrow.

Zuckerkandl* has also noticed these two orbital limbs, and has very truly observed how easy it would be to mistake the external one for the true anterior horizontal limb in cases where the latter is weakly developed, or entirely absent.

But Eberstaller has given the fullest and the best account of these orbital limbs. He terms them the "third and the fourth anterior limbs of the Sylvian fissure," and he has found the former (*i. e.* the external) present in 22 per cent. of the hemispheres he has examined, whilst the internal was only found in 13 per cent. Further, he has shown that the external orbital limb is much more frequently present on the right side (viz. in the proportion of 15 to 7). The results which I have obtained coincide very closely with those given by Eberstaller. Thus I found that the external orbital limb occurs very nearly with equal frequency in the two sexes, although it shows a slight preference for the male. It was found, however, in 11 per cent. on the right side, and in only 6 per cent. on the left. It is further very evident that the development of the external orbital limb is in a measure correlated with that of the true anterior limbs. Thus, it is found more commonly in those hemispheres in which the latter are deficient. In cases where there is only a single anterior limb, it occurs most frequently; and it is observed oftener in connexion with the Y condition of the anterior limbs than in cases where the two anterior limbs are completely separate.

I have applied the term "orbital" to these limbs, and have not adopted the terminology of Eberstaller, because these short fissures when they exist have no claim to be placed in the same category with the true anterior limbs of the Sylvian fissure. It is true that they generally cut through the entire thickness of the orbital operculum, but they fail to come up to our

* "Ueber den Einfluss des Nahtwachsthumes und der Schädelform auf die Richtung der Gehirnwindungen," Medizinische Jahrbücher, 1883, III. und IV. Heft, p. 449.

definition of an "anterior limb," in so far that they are not developed as primitive deficiencies in the orbital operculum. They do not appear until the eighth month, when the orbital operculum is well formed. A slight notch on the margin of the operculum is all that indicates the presence of the external orbital limb at this stage. This gradually deepens until it cuts right through the operculum.

Eberstaller has called attention to the connexion which exists between the external orbital limb and the gyrus accessorius of the island of Reil, and has shown that even when the fissure is absent on the surface it may be recognized on the deep surface of the orbital operculum. To this aspect of the question we shall require to return when we are considering the convolutions on the surface of the insula.

IV. **Convolutions and Sulci on the Surface of the Insula.**—The admirable description of the gyri and sulci on the surface of the island of Reil which has been given by Eberstaller* leaves little to be desired, in so far as the adult brain is concerned. He points out that the insula is divided into an anterior and a posterior part, which are quite distinct from each other, by a sulcus which lies in the same plane, and presents the same direction as the fissure of Rolando. This furrow had previously been noted by Hefftler† and Guldberg,‡ and the latter author has suggested for it the very appropriate name of sulcus centralis insulæ, which indicates not only its central position in the island of Reil, but also its relation to the central fissure on the outer face of the hemisphere mantle. The portions of the island of Reil which lie in front of, and behind this sulcus Eberstaller has termed the insula anterior and the insula posterior.

It will be necessary for me to state briefly the further points in the anatomy of the island of Reil, which have been elucidated by Eberstaller,

* "Zur Anatomie und Morphologie der Insula Reillii," Anatomischer Anzeiger, No. 24, 15 Nov., 1887, p. 739.

† *Vide* a Report upon Dr. Hefftler's Inaugural Dissertation upon "Die Grosshirnwindungen des Menschen und deren Beziehungen zum Schädeldach," by Prof. Landzert, in the Archiv für Anthropologie, Band x., 1878.

‡ "Zur Morphologie der Insula Reillii," Anatomischer Anzeiger, No. 21, 1. October, 1887, p. 659.

in order that I may be able to render intelligible the few additions to his description which I wish to make, as well as the facts relating to the development of the convolutions and sulci of the insula, which I have observed. According to Eberstaller the anterior insula is connected entirely with the frontal lobe, whilst the posterior insula is exclusively connected with the parietal and temporal lobes.

The anterior insula presents three gyri which unite below to form the pole of the island of Reil, whilst above they are separated from each other by two sulci. These three convolutions Eberstaller names from before backwards, the gyrus brevis primus, the gyrus brevis secundus, and the gyrus brevis tertius (fig. 27). The gyrus primus and the gyrus tertius are, as a rule, strongly marked, whilst the intermediate one is more weakly developed. It appears to me that a better name for the gyrus tertius would be the gyrus centralis anterior, seeing that this term would indicate its position with reference to the central sulcus, and at the same time show its relation to the anterior central (or ascending frontal) convolution on the outer face of the hemisphere. The gyrus tertius is continued downwards on the surface of the island of Reil, very much in the direction of the ascending frontal convolution, and its upper end lies concealed under that part of the fronto-parietal operculum which is formed by this convolution of the frontal lobe. Of the two sulci which separate the three gyri breves, the anterior, termed by Eberstaller the sulcus anterior, is always well expressed, but it rarely reaches so low as the pole of the anterior insula. For reasons which will become more apparent afterwards, the term sulcus præcentralis Reillii, proposed by Guldberg would be more appropriate for this sulcus. As a rule the second sulcus is merely a shallow depression of a triangular form which intervenes between the upper portions of the gyrus secundus, and the gyrus tertius.

But Eberstaller describes two additional gyri in connexion with the anterior insula. These he terms the gyrus transversus and gyrus accessorius. The gyrus transversus extends forwards from the pole of the island, and is of the nature of an annectant gyrus, seeing that it connects the lower part of the insula anterior with the under, or orbital face of the frontal lobe. When superficial, as, indeed, it very frequently is, it is interposed

as a barrier between the lower end of the furrow which limits the island of Reil in front and the vallecula Sylvii. Sometimes, however, it is depressed and deep, and then a superficial connexion occurs between the anterior limiting furrow of the insula and the vallecula.

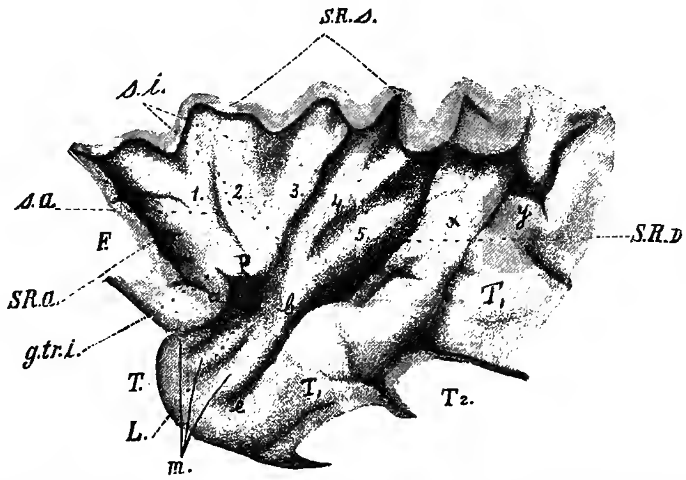


Fig. 27.—Eberstaller's figure illustrative of the fissures and gyri on the surface of the human insula. (From the Anatomischer Anzeiger, No. 24, 1887, with permission.)

1.	Gyrus brevis primus,	Insula anterior.
2.	Gyrus brevis secundus,	
3.	Gyrus centralis anterior,	
4.	Gyrus centralis posterior,	Insula posterior.
5.	Gyrus posterior secundus,	
S.R.a.	Sulcus Reillii anterior.	
S.R.s.	Sulcus Reillii superior.	
S.R.p.	Sulcus Reillii posterior.	
L.	Limen insulæ.	
P.	Pole of the insula.	
F.	Orbital part of the inferior frontal convolution.	
T.	Pole of the temporal lobe.	
T_1.	Superior temporal convolution.	
T_2.	Middle temporal convolution.	
x.y.	Transverse convolutions of Heschl.	
s.i.	Sulcus centralis insulæ.	
s.a.	Sulcus præcentralis.	
g.tr.i.	Gyrus transversus, which is represented as passing into the inner end of the orbital operculum (*a*).	
e.	The transverse furrow on the deep surface of the temporal pole, with which, in the adult, the posterior or inferior limiting sulcus of the insula, becomes continuous.	
m.	Gyri on the upper surface of the temporal pole.	

The gyrus accessorius is placed to the outer side of the gyrus transversus. It stretches forwards from the fore-part of the gyrus brevis primus, and lies under cover of the orbital operculum at a lower level than the anterior horizontal limb of the Sylvian fissure. As Eberstaller has pointed

out, this small convolution is frequently carried right across the anterior limiting sulcus of the insula, and becomes continuous, with a corresponding gyrus on the deep surface of the outer part of the orbital operculum. Eberstaller lays great stress upon the connexion which he believes to exist between the gyrus accessorius and the external orbital limb of the Sylvian fissure. He states that in cases where this limb is absent there is a corresponding furrow on the deep surface of the orbital operculum which exactly overlies the gyrus accessorius. We would point out, however, that this furrow should be considered as being more in relation to the sulcus on the surface of the insula which bounds the gyrus accessorius on its mesial aspect, because, when the gyrus in question is carried across the anterior limiting sulcus, it joins that part of the orbital operculum which lies between the anterior horizontal and the external orbital limbs of the Sylvian fissure.

The posterior insula is divided by a well-marked sulcus, which may be called the sulcus postcentralis Reillii, into two convolutions which lie one in front of the other. This furrow extends upwards and backwards into the posterior part of the superior limiting furrow of the island of Reil, but in front and below the two convolutions unite beyond it. For the anterior convolution which is covered at its upper end by that part of the fronto-parietal operculum which is formed by the base of the ascending parietal convolution Eberstaller employs the term suggested by Giacomini, viz. the gyrus longus; but it would be much better named the posterior central gyrus—a term which would not only indicate its position with reference to the sulcus centralis, but also its relation to the posterior central convolution on the outer face of the hemisphere. The posterior convolution of the posterior insula Eberstaller terms the gyrus posterior secundus. The upper end of this convolution stands in relation to the forepart of the supramarginal convolution of the parietal lobe.

As we have seen, the two gyri of the posterior insula unite below the post-central sulcus, and are then continued onwards by a common stem. This is separated from the pole of the anterior insula by the sulcus centralis, and Eberstaller considers that it is carried on to the deep surface of the extremity of the temporal lobe, on which it can be traced to the temporal pole.

Certainly, in the adult the condition of affairs presents this appearance (fig. 27); but we shall see later on that a study of the development of the parts clearly indicates that the connexion is not with the temporal lobe, but with the great limbic lobe.

There is thus a very close correspondence between the convolutions and sulci on the surface of the island of Reil and those on the lateral surface of the hemisphere. The two central convolutions (*i. e.* gyrus brevis tertius and gyrus longus of Eberstaller) correspond with the two central convolutions (ascending frontal and ascending parietal), and the three fissures, viz. the sulcus præcentralis Reillii the sulcus centralis, and the sulcus postcentralis Reillii, are in every respect comparable with the sulcus præcentralis inferior, the fissure of Rolando, and the vertical limb of the intraparietal fissure on the surface of the mantle. It is true that we cannot regard these corresponding convolutions and sulci as being directly continuous with each other, but still in many cases something which approaches very nearly to continuity occurs. Thus it is well-known that the inferior præcentral sulcus, the fissure of Rolando, and the intraparietal sulcus are not unfrequently carried downwards so as to cut into the fronto-parietal operculum and open into the Sylvian fissure. Eberstaller has pointed out that when this occurs in the case of the fissure of Rolando the condition is brought about by the extension upwards round the lower margin of the operculum of a small variable furrow which he terms the inferior transverse sulcus of the fissure of Rolando. This undoubtedly belongs to the same system as the fissure of Rolando and the sulcus centralis Reillii; in other words, it is to be regarded as the connecting link. The extension of the intraparietal into the fissure of Sylvius is effected in precisely the same manner. A small variable opercular furrow extends upwards into it and acts as a loose bond of union between it and the postcentral sulcus of the insula. I am not able to speak with the same certainty of the two præcentral sulci. These two furrows, the one on the surface of the insula and the other on the surface of the mantle, are more strongly marked in the fœtus than in the later stages of development, and consequently their relations in the adult cannot be studied with the same precision. When the inferior præ-central sulcus on the surface of the

mantle communicates with the fissure of Sylvius, it does so by joining either the inferior transverse furrow of the fissure of Rolando, or the sulcus diagonalis of Eberstaller. It is possible that the latter furrow constitutes the connecting link between the two præcentral sulci. When we come to deal with the development of the sulci on the insula we shall see that the præcentral sulcus becomes slightly shifted in a forward direction, so that it does not accurately coincide in its direction in the adult with the corresponding furrow of the frontal lobe.

But further, the inferior frontal convolution stands in close connexion with the portion of the anterior insula which is placed in front of the præcentral sulcus of the island of Reil. Thus the gyrus brevis primus in its upper part lies under cover of the pars triangularis, and not infrequently pushes itself across the upper limiting sulcus of Reil to form a direct connexion with this part of the lower frontal convolution. The gyrus accessorius stands in precisely the same relation to that part of the orbital portion of the inferior frontal convolution which lies between the anterior horizontal limb of the Sylvian fissure and the posterior extremity of the external orbital sulcus. The connexion between the sulcus which limits the gyrus accessorius below and the external orbital sulcus on the orbital face of the frontal lobe is also apparent. This sulcus is continued on to the deep surface of the orbital operculum, and in certain cases cuts right through it to form the external orbital limb of the Sylvian fissure. Benedikt terms this limb the "hinder piece" of the orbital sulcus, and remarks that he has observed the two fissures to become continuous with each other. This condition I have never seen; but be this as it may, I regard the external orbital limb of the Sylvian fissure in the same light as I do the inferior transverse sulcus of the fissure of Rolando of Eberstaller. It is a secondary fissure in the operculum which is to be regarded as an intermediate piece between the sulcus on the insula which bounds the gyrus accessorius below and the external orbital sulcus on the orbital face of the frontal lobe.

But a very considerable amount of variation is to be noted in the arrangement of the gyri in the forepart of the insula, and it is of importance to observe that this goes hand in hand with variations in the

corresponding part of the inferior frontal convolution. A disturbance in the condition of the one is generally accompanied by a disturbance in the condition of the other.

V. **Development of the sulci and gyri on the surface of the insula.**— A study of the manner in which the convolutions and sulci of the insula are developed reveals many points of high importance and interest. Up to the middle of the fifth month the surface of the insula remains perfectly smooth, but long before this there is a marked indication of its division into a frontal and a parieto-limbic portion. From its very earliest appearance the fossa Sylvii is encroached upon below by the vallecula Sylvii. When the hemisphere is viewed in profile the latter region appears as a semilunar depression which indents the lower part of the Sylvian fossa and occupies a position between the extremity of the temporal lobe and the under aspect of the frontal lobe. This notch or depression is surrounded above by a rim which represents the external root of the olfactory lobe, and it divides the lower part of the Sylvian area into two nearly equal portions, viz. an anterior portion which joins the under surface of the frontal lobe and a posterior part which runs into the extremity of the temporal lobe (Pl. II., figs. 2, 3, 4). As the temporal operculum begins to take shape and the extremity of the temporal lobe grows forwards so as to overshadow the Sylvian vallecula, the hinder part of the lower portion of the insula becomes hidden from view, whilst the fore-part developes into the pole of the insula. At the same time the wide semilunar notch in the lower part of the insula, or, in other words, the outer extremity of the vallecula Sylvii becomes gradually reduced in width and converted into a narrow cleft or incision (Pl. I., figs. 21, 22, and 23). Further, with the growth of the temporal operculum the lower limiting furrow (lower part of the sulcus circularis Reillii of Schwalbe) becomes apparent.

When the front extremity of the temporal lobe of a fœtal brain (say at the fifth month) is examined, two very distinct gyri, which traverse it from above downwards immediately external to the uncus, are evident. The outer of these is the extremity of the temporal operculum (Pl. I.,

fig. 21, 1); the inner gyrus is continuous with the hinder part of the insula (Pl. I., fig. 21, 2), and lies close to the outer side of the front end of the uncus (Pl. I., fig. 21, 3), which, as is well known, very early takes shape (Pl. II., figs. 2, 7, 22, and 23; and Pl. I., figs. 21, 22, and 23). These may be termed the primitive polar gyri of the temporal lobe, and in the figures in Plates I. and II. in which they are depicted they are marked 1 and 2, whilst the uncus is marked 3. A faint furrow intervenes between them, but they are rendered more conspicuous by their own prominence than by the presence of the intervening sulcus. This sulcus is quite continuous with the posterior limiting sulcus of the insula, and when followed round the temporal pole it is seen to lie directly in the line of the depression, along the bottom of which the collateral fissure is afterwards developed. Later on it may become a distinct and sharply-cut fissure, the incisura temporalis of Schwalbe. Coincident with this change the inner of the two polar gyri, which is continuous with the hinder part of the insula, decreases in size and prominence until in the eighth month it becomes more or less completely incorporated with the uncus.

The inferior limiting sulcus of the insula, the incisura temporalis which bounds the extremity of the uncus on its outer side, and the collateral fissure lie therefore all in the same line, and may be regarded as the bounding fissures of the temporal lobe. The inferior limiting sulcus of the insula marks it off from the island of Reil; while the incisura temporalis and the collateral fissure intervene between it and the great limbic lobe. But further the growth forward of the extremity of the temporal pole is merely a growth of the anterior part of the temporal operculum which, as we have seen, first shows as the outermost of the two primitive polar gyri. It extends forwards to meet the orbital operculum, and finally comes to overlap it to a very considerable extent. There is no part of the opercular arrangement which ultimately attains so great a depth.

Using the term "temporal pole," therefore, in its more restricted sense (that is to say excluding the extremity of the uncus), it is important to note that this part of the temporal lobe owes its existence to the forward growth of the operculum.

But in the later stages of development the very evident relation which the inferior limiting sulcus of the insula bears to the incisura temporalis and the collateral fissure becomes obscured. Towards the end of fœtal life the deep surface of the temporal pole becomes scored with two or three transverse sulci. These have been figured and described in the adult brain with great care and exactness by Eberstaller; * and the same author has very correctly pointed out that in the adult the lower limiting sulcus of the insula usually ends in front by running forwards upon the deep surface of the temporal pole and taking up a position parallel to and behind these transverse sulci (fig. 27, p. 97). This, however, is a purely adventitious arrangement which is brought about through one of the transverse sulci, about the ninth month of fœtal life, running into the limiting sulcus of Reil, and thus becoming continuous with it. In the adult brain, therefore, the true relations of the inferior limiting sulcus of the insula are somewhat misleading.

In the ape the transverse sulci on the deep surface of the temporal pole are not developed, and the incisura temporalis is generally well-marked. The relation which exists between the posterior part of the insula and the uncus can thus be seen to great advantage, and also the continuity between the inferior limiting sulcus of the insula and the incisura temporalis confirmed.

The examination of the fœtal brain renders the relationship which exists between the sulci and convolutions of the insula and the fissures and gyri on the surface of the mantle still more obvious. Three radial "Primärfurchen" appear in each region, not only at the same stage in the development of the brain, but also as a rule in very much the same order. In the latter half of the fifth month the central sulcus becomes evident as a faint line or furrow which runs upwards and backwards from the lower part of the Sylvian fossa (Pl. II., figs. 12 to 15, *2*). From the very first it lies accurately in the line of the fissure of Rolando, and it appears at the same date. At this period the sulcus centralis is situated much nearer to the hinder end of the insula than in the later stages, because the Sylvian fossa

* Anatomischer Anzeiger, No. 24, Nov., 1887, p. 745.

has not yet attained its full degree of backward extension. In all the subsequent changes which occur in this region the sulcus centralis remains absolutely fixed and stationary, and sways neither in a forward nor in a backward direction.

The præcentral sulcus is developed a little later than the central sulcus, but as a general rule it comes into view before the end of the fifth month (Pl. II., figs. 13, 17, 19, and 20, I). It lies accurately in line with the sulcus præcentralis inferior on the surface of the frontal lobe; but in its subsequent history it is not so stationary as the sulcus centralis. In the last four weeks of fœtal life its upper end generally moves forwards to a slight extent, so that, in a measure, it loses its accurate relationship to the corresponding sulcus on the surface of the mantle. Another peculiarity of this sulcus consists in the fact that in the early stages of its development it outstrips the central sulcus, and for a time it becomes the best marked furrow on the surface of the insula. This pre-eminence it generally loses in the eighth month. In fact, as we have seen, it is in the adult the feeblest sulcus of the series. In connexion with this it is of interest to note that very much the same thing frequently occurs in the case of the præcentral fissure of the frontal lobe. In many cases, more especially when it appears earlier than the fissure of Rolando, it is extremely deep, and much the most evident of the three radial "Primärfurchen" on the mantle. Later on, however, it falls behind the others in its degree of development. Pansch * held it as a law that there is a general correspondence between the depth of a furrow and its period of origin: in other words, the earlier a furrow makes its appearance in the fœtal brain, the deeper will it be in the adult brain in comparison with others of more recent development. This law is no doubt true in the main, but there are some exceptions, and the case in point is one of these.

Guldberg,† in his excellent paper on the "Morphology of the Island of Reil," has mistaken in the fœtal brain the sulcus præcentralis for the sulcus centralis of the insula, and to account for its subsequent change in position

* "Einige Sätze über die Grosshirnfaltungen," Centralblatt für die Medicinischen Wissenschaften, No. 36, Sept. 8, 1877.

† Anatomischer Anzeiger, October, 1887, No. 21.

he has supposed that its upper end is gradually pushed backwards until it assumes a situation and direction which brings it into a line with the fissure of Rolando. He is therefore obliged to assume "that the frontal lobe of the cerebrum increases during growth relatively more than the part which is placed behind the sulcus centralis insulæ." We know that this is not the case, because if it were we should also have the position of the fissure of Roland affected, and this is almost as stationary and fixed after its first appearance as the sulcus centralis insulæ. But further the Sylvian fossa has a growth peculiar to itself. The anterior end of the fossa maintains throughout its entire growth very much the same relative position, whereas the posterior end extends rapidly backwards. But this backward growth does not affect the entire area: it seems to be brought about by a continual backward retreat of the surrounding mantle-wall, so that the position of the sulci when once they are laid down is not interfered with.

The post-central sulcus is much later in making its appearance. As a rule it does not show until the middle of the sixth month, or even later. Its development nearly coincides with that of the intra-parietal sulcus. It would not be possible for this sulcus to take form at a date much earlier than this, because the ground which it occupies on the insula has hardly been included within the Sylvian area, at the time when the two other sulci appear.

The period at which the three radial furrows of the insula can be best studied, in their relations to the corresponding sulci on the surface of the cerebral mantle, is in the latter part of the seventh month, or the first part of the eighth month (Pl. I., fig. 33, and Pl. IV., fig. 1). Still, it is right to state that exceptional cases are met with, and I have observed fœtal brains which had very nearly reached this stage in which the insula was perfectly smooth. Further, there is good reason to believe that, in the development of the sulci and gyri, the right insula is usually in advance of the left, and also that the process is greatly retarded in the female brain. Rudinger * has contended that all the convolutions of the cerebrum of the female fœtus are backward in their growth as compared with those in the brain of the male fœtus. Upon this point I have not been able to satisfy myself, because

* Ueber die Unterschiede der Grosshirnwindungen nach dem Geschlecht beim Fœtus und Neugeborenen. München, 1877.

we meet with cerebral hemispheres belonging to the same period of development and to the same sex, which present very different degrees of complexity. In the case of the insula the law certainly does appear to hold good.

The following is a brief account of the condition of the insula in those fœtal brains which I have specially examined with the view of determining the development of the gyri and sulci :—

I. 5 *to* $5\frac{1}{2}$ *months*—6 hemispheres examined.

In three, . . Insula perfectly smooth (viz. 1 right and 2 left).
In two, . . Insula with sulcus centralis only (1 right and 1 left).
In one, . . Insula with sulcus præcentralis and sulcus centralis (right).

II. $5\frac{1}{2}$ *to* 6 *months.*—10 hemispheres examined.

In two, . . Insula perfectly smooth (both left).
In four, . . Insula with sulcus centralis only (2 right and 2 left).
In four, . . Insula with sulcus centralis and sulcus præcentralis (3 right and 1 left).

III. 6 *to* $6\frac{1}{2}$ *months.*—8 hemispheres examined.

In one, . . Insula perfectly smooth (right).
In one, . . Insula with sulcus centralis alone (left).
In three, . . Insula with sulcus centralis and sulcus præcentralis (2 right and 1 left).
In three, . . Insula with three sulci (2 right and 1 left).

IV. $6\frac{1}{2}$ *to* 7 *months.*—3 hemispheres examined.

In each of these the insula showed all the three sulci.

In the latter weeks of intra-uterine life the development of the gyri and sulci on the surface of the insula takes place very rapidly. Consequently, at birth the insula presents very nearly the same convolution-pattern that it does in later life. All the details are filled in, and, as we have noticed, the præcentral furrow, instead of having fallen back, as Guldberg supposed, to form the sulcus centralis, has in reality moved very slightly forwards, so that it does not lie so accurately in line with the corresponding furrow on the mantle as it did on its first appearance. This is brought about by the formation of that triangular depression which marks off the gyrus brevis secundus from the gyrus centralis anterior (gyrus brevis tertius).

VI. **Antero-posterior length of the Island of Reil.**—We have seen that, from its first appearance to the end of fœtal life, there is a steady and rapid increase of the area of the Sylvian fossa, and further, that this growth is relatively much greater than that of the cerebral hemisphere, as a whole, during the same period. It is now necessary to establish the ratio which the same area (viz. the insula) presents to the cerebral hemisphere from the time of birth up to adult life. If we again assume the lateral length of the hemisphere to be equal to 100, the following Table will show the percentage of this which is formed by the insula, and also of the portion of cerebrum in front of it, and the portion of cerebrum behind it, at different periods of extra-uterine life.

It must be clearly understood, however, that by the "lateral length" of the hemisphere in this instance we mean the sum of the following measurements: (*a*) from anterior end of cerebrum to the anterior end of the insula; (*b*) the length of the insula; and (*c*) the distance between the posterior end of the insula and the occipital pole:—

RELATIVE LENGTH OF THE ISLAND OF REIL.

Lateral length of the Cerebral Hemisphere = 100.

Period of Development.	Number of Hemispheres Examined.	Fronto-Central Index.	Central or Insular Index.	Occipito-Central Index.
7½ to 8 months,	12	26·5	28·7	44·8
Full-time fœtuses,	11	24·3	32	43·6
12 months,	8	25·3	30	44·7
4 to 5 years,	7	27·1	28·8	44·1
11 to 15,	6	26·8	29·1	44·1
Irish adults,	28	26·3	29·6	44·1
Adult Negroes,	5	28·7	28·3	43

From this Table it will be seen that the posterior end of the insula maintains after birth a wonderfully constant position with reference to the posterior end of the cerebrum. Slight variations, it is true, are

exhibited in the course of the first twelve months, but from the fourth year up to adult life the average percentage distance of the hinder end of the island of Reil from the posterior extremity of the occipital lobe was the same for each period examined, viz. 44·1. The same constancy of position, however, does not exist for the anterior limit of the insula. In the full-time brain the island of Reil attains its maximum length (32), and approaches most nearly to the anterior end of the hemisphere (24·3). From this period on to adult life it falls back slightly, and finally attains an index of 29·6. It is extremely interesting, therefore, to note, that whilst during intra-uterine life the anterior limit of the insula maintains a nearly fixed relation to the anterior end of the cerebrum, and the posterior end an extremely varying relation to the posterior extremity of the occipital lobe, towards which, indeed, it steadily and rapidly grows, in extra-uterine life the reverse condition is observed. The posterior end of the region is fixed, whilst the anterior limit oscillates—at first approaching more closely to the anterior end of the cerebrum, and then falling back to the position which it occupied during intra-uterine life.

In the foregoing Table I have included the results which I obtained from the measurement of five negro brains. The island of Reil in these appear to be smaller than in the European brain. Further, its anterior limit is at a relatively greater distance from the fore end of the cerebrum, whilst its hinder end approaches more closely to the occipital extremity of the hemisphere. The number of specimens examined is certainly too small to justify us in drawing any final deductions from these points of comparison between the European and negro brains. I excluded from this inquiry six negro hemispheres which were distorted; the five which I selected for measurement were not hardened with the necessary precautions for the thorough preservation of external configuration.

But the question of sex and side must also be studied in connexion with the area occupied by the insula. In so far as sex is concerned, no decided difference was apparent in the early stages of the island of Reil in the male and female. But in adults there seems to be good reason to believe that in the male brain the antero-posterior length of the island of Reil is relatively greater than in the female. The following are the indices:—

Relative Length of the Island of Reil in the Adult Brain in the two Sexes.
Lateral Length of Hemisphere = 100.

Number of Hemispheres Examined.		Fronto-Central Index.		Central Index.		Occipito-Central Index.	
Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.
14	11	25·3	27·8	30·3	28·4	44·3	43·7

My own impression is that the difference between the two sexes is in this Table more accentuated than it is in reality, and that had I examined a larger number of hemispheres it would, in all probability, have been somewhat lessened.

The figures which I have obtained, however, in connexion with my comparison of the right and left hemispheres, renders it probable that at all periods of life there is a relatively greater development of the island of Reil on the left side than on the right. The following Table shows this:—

Relative Length of the Island of Reil in the Right and Left Hemisphere.
Lateral Length of Cerebrum = 100.

Period of Development.	No. of Hemispheres Examined.		Fronto-Central Index.		Central Index.		Occipito-Central Index.	
	Right.	Left.	Right.	Left.	Right.	Left.	Right.	Left.
4½ to 5 months, . .	3	2	28·1	24·5	22·8	24·4	49·1	51·1
5 to 5½ months, . .	5	5	25·8	25·7	23·8	24·8	50·4	49·5
5½ to 6 months, . .	5	6	25·9	25·5	25·8	25·9	48·3	48·6
6 to 6½ months, . .	5	4	26·1	26·5	26·1	26·4	47·8	47·1
6½ to 7½ months, . .	2	1	26·2	26·1	28·4	27·2	45·4	46·7
7½ to 8½ months, . .	6	6	26·4	26·5	28·4	29	45·3	44·4
Full-time fœtus, . .	6	5	24·6	23·9	31·6	32·5	43·8	43·6
First 12 months, . .	5	3	26·6	23	28·1	33·2	45·3	43·8
4 to 5 years, . .	3	4	27·1	27·1	30	27·9	42·9	45
11 to 12 years, . .	2	3	27·2	26·6	29	29·1	43·6	44·3
Adults, . . .	16	12	26·5	25·9	29·2	30·1	44·3	44

The difference in extent of the insula on the two sides of the brain is very slight, but it is seen in every stage indicated above, with the exception of the six and a-half to seven and a-half months' fœtal period, and the four to five years' child. In both of these cases, however, it will be observed that the number of hemispheres examined was very small.

VII. **The Sylvian Region in the Ape.**—One of the most remarkable characters of the cerebrum in the chimpanzee and the orang is the total absence of the frontal and orbital opercula. The temporal and parieto-frontal opercula are alone present. Pansch incidentally alludes to this. He says: "Wichtiger noch ist das Resultat, dass an der ganzen sogenannten Orbitalfläche keine Ueberwucherung des Mantels stattgefunden hat, so dass hier also Insel und Mantel in demselben Niveau liegen. Der hier vorhandene Ramus ascendens fossæ Sylvii ist also nicht wie beim Menschen eine zwischen zwei wuchernden Lappen gebildete Furche, sondern nur der freie Rand des gewucherten obern Lappens."*

There is a so-called anterior limb of the Sylvian fissure, but it does not come within the description which we have given of such a limb. As Pansch has observed, it bounds the parieto-frontal operculum in front, and the fore-border of this operculum forms its superficial wall. It cuts obliquely backwards and inwards into the hemisphere, and the surface of its deep wall is carried, in some cases (in the chimpanzee) almost continuously on to the surface of the island of Reil. Pansch, however, is hardly correct in saying that the insula and the mantle lie in the same plane.

But it may be asked why we have so decidedly stated that the frontal operculum (pars triangularis) is absent in the anthropoid, seeing that we might very well suppose that it was merely fused with the fore-part of the parieto-frontal operculum. This is, no doubt, the view of those who hold that the so-called "anterior limb" of the Sylvian fissure is homologous with the anterior horizontal limb in man. Broca † has given expression to this view, and Hervé‡ has repeated, with emphasis, the same opinion. Both of

* "Ueber die typische Anordnung der Furchen und Windungen," &c., Archiv f. Anthrop., Dritter Band, p. 245.

† Morphologie du cerveau de l'homme et des primates.—Revue d'Anthropologie, 1878, 2e Série, t. 1er.

‡ La Circonvolution de Broca. Paris, 1888.

these authors describe in the chimpanzee and orang an occasional ascending limb of the fissure of Sylvius. Hervé states that he has seen this additional limb once in five chimpanzee brains, and twice in a similar number of brains from the orang, and he goes on to affirm that when it exists, "il en résulte la formation, entre elle et la branche horizontale antérieure, d'un cap plus ou moins arrondi, et alors, au premier abord, F_3 (*i. e.* the inferior frontal convolution) semble décrire sur ces deux branches un double méandre." He further observes, that this supposed ascending limb cuts the operculum behind the præcentral sulcus, and is therefore a fissure in the basal part of the ascending frontal convolution. We refuse to consider a fissure in such a position as presenting anything in common with the ascending limb of the Sylvian fissure in man. Much more likely is it the representative in the anthropoid ape of the sulcus transversus inferior of Eberstaller, the intermediate link between the sulcus centralis insulæ and the fissure of Rolando.

But there are other and more cogent facts which may be urged against the view advanced by Broca and Hervé. If we are to regard the anterior limb of the Sylvian fissure which bounds the fronto-parietal operculum in front in the anthropoid brain as homologous with anything, it must be with the ascending limb of the human brain, and for this reason: *the part of the island of Reil which corresponds to the frontal operculum or pars triangularis in man is absent in the chimpanzee.* In other words, there is no submerged gyrus brevis primus insulæ in the chimpanzee brain. X ?

I restrict the term "insula" in this case to the part of the brain-surface which is covered by the two opercula—parieto-frontal and temporal. It may be necessary at a future time to discuss whether or not a portion of the insula, as it exists in man, is not on the surface of the hemisphere of the anthropoid ape, and fully exposed to view. In other words, we may require to decide whether a portion of the so-called inferior frontal convolution in the anthropoid is not in reality the equivalent in the ape of the front part of the island of Reil in man. If this be the case, the sulcus anterior Reillii in man is the sulcus fronto-orbitalis in the anthropoid.

This leads us to speak of the gyri and sulci on the surface of the island of Reil in the anthropoid brain. These are very poorly developed, and

resemble the corresponding convolutions in man during their early stages of development. In the chimpanzee the sulcus, which is generally supposed to be the anterior limiting furrow of the insula is often very feebly marked (Pl. IV., fig. 9), and the surface of the island of Reil passes almost continuously over the deep wall of the so-called anterior limb of the Sylvian fissure on to the free surface of the mantle. When a well-marked anterior limiting sulcus does exist for the submerged portion of the insula, it lies in the same line as the præcentral sulcus of the mantle.

As a rule, there are two oblique furrows on the surface of the insula. One occupies a plane, and presents a direction more or less similar to that of the fissure of Rolando, and therefore may be regarded as the fissura centralis; the other, more faintly marked, lies in the line of the postcentral portion of the intraparietal sulcus, and, therefore, is the representative of the postcentral sulcus of the human insula. There are, therefore, only three convolutions, as a rule, on the surface of the submerged portion of the insula of the chimpanzee, and these are homologous with the gyrus centralis anterior (gyrus brevis tertius of Eberstaller), gyrus centralis posterior (gyrus longus of Eberstaller and Giacomini), and a narrow strip, the gyrus posterior secundus (Pl. IV., fig. 9).

In the orang, the island of Reil is somewhat more extended, and a nearer approach to man is attained. The anterior limiting sulcus of the submerged portion lies slightly in front of the line of the præcentral sulcus on the mantle, and there are three radiating furrows which represent the three radial "Primärfurchen" of the mantle, and which exhibit a close similarity to the condition observed in the early human fœtal brain. The convolutions are from before backwards: (1) the gyrus brevis primus; (2) the gyrus centralis anterior; (3) the gyrus centralis posterior; (4) the gyrus posterior secundus (Pl. IV., fig. 11).

The insula in the orang, therefore, in so far as its convolutions are concerned differs from the insula in man in the absence of the gyrus accessorius, and the gyrus brevis secundus; whilst the chimpanzee differs from the orang in the absence of the gyrus brevis primus. Further, in the anthropoid brain the insula is not divided so perfectly by the central sulcus into an anterior frontal and a posterior parieto-limbic part.

Each of the four chimpanzee brains which I possess accords more or less closely with the above general description, but there are individual differences to be noticed in the degree of development of the different convolutions and sulci. Further, on the under surface of the polar projection of the island there is usually a small furrow which runs in the line of the sulcus centralis and ends in the vallecula Sylvii. This limits a distinct gyrus transversus or annectant gyrus, which extends from the fore-part of the insular pole to the orbital aspect of the frontal lobe. The furrow itself is no doubt a detached part of the sulcus centralis.

In the orang there is no evidence of a gyrus transversus, or any other direct bond of union between the polar projection of the island and the under surface of the frontal lobe.

In the anthropoid, one transverse furrow on the deep surface of the temporal pole is usually present, but this does not obscure the connexion between the inferior limiting sulcus of the island of Reil and the incisura temporalis, and the continuity of the posterior insula with the uncus.*

It is curious that while the anthropoid ape should be so absolutely

* Since the foregoing was sent to the printer I have received, through the courtesy of the author, an interesting communication by Professor Waldeyer[1] upon the Sylvian fissure and the insula in the gibbon. This paper is illustrated by four beautiful drawings, which show that in this member of the anthropoid group the sulcus centralis insulæ is usually, although not constantly, present. The author considers that the insula may be regarded in the gibbon as forming a single simple convolution bent around a central furrow, and would seem to infer that we have here a condition which may be regarded as affording us a "ground-plan," by means of which an affinity with the carnivore type may be established. I do not agree with this view of the case, as may be inferred from the foregoing. Waldeyer further remarks (p. 10): "Die pars frontalis der Insel biegt nun in die dritte Stirnwindung um, die pars parieto-temporalis in die obere (erste) Schläfenwindung, grade wie man es beim Meschen findet." Although he refers us to the drawings which he publishes for confirmation of this statement, I cannot see any connexion whatever between the posterior insula and the first temporal convolution. If there is, it must be of an entirely adventitious character because, as we have seen, the true primitive connexion of this part of the island is not with the temporal lobe but with the limbic lobe.

[1] Sylvische Furche und Reil'sche Insel des Genus Hylobates.—Sitzungsberichte der k. Preussischen Akad. der Wiss. Berlin, März 19, 1891.

destitute of a frontal and an orbital operculum, there are many of the lower apes, as, for example, the baboon, the macaque, hamadryas, cercopithecus, &c., which show a faint trace of an operculum in this locality, although it cannot in any respect be regarded as being equivalent to the same structure in man. When the temporal lobe is pulled well downwards the outer portion of the orbital part of the frontal lobe is seen to be undermined to a slight extent. A structure resembling a feeble orbital operculum is thus formed, which is directly continuous with the fore-part of the fronto-parietal operculum. These meet at an angle, and on examining them from below it will be observed that the deep surface of the operculum at this angle is deeply scored by a furrow which rarely reaches the surface (Pl. IV., fig. 10). The question, of course, arises: can this be the representative, in the lower apes, of an anterior limb of the Sylvian fissure? I am satisfied that it is not. It lies immediately below, and in the same line as the præcentral sulcus, and is to be regarded rather, I believe, as the outer branch of a bifurcation of the anterior limiting furrow of the island of Reil.

In the lower apes the sulci on the surface of the elliptical and very projecting island of Reil are, as a rule, feeble and variable. Sometimes the surface is perfectly smooth (Pl. IV., fig. 8); at other times, as in the chimpanzee, there may be two furrows, or perhaps only one. In the hamadryas, and occasionally in the baboon, I have observed the three radial sulci, as they exist in the orang. In almost all my specimens there is a well-marked gyrus transversus connecting the pole of the insula with the orbital surface of the frontal lobe. The following was the condition found in the different brains of the low apes which I examined :—

I. *The Macaque.*—Five cerebral hemispheres examined.

In one, . .	Insula quite smooth.
In two, . .	Sulcus centralis Reillii alone present.
In one, . .	Sulcus centralis and sulcus postcentralis present.
In one, . .	A faint Y-shaped furrow. The two limbs joining a stem, which was continued downward and forward toward the insular pole.

II. *Baboon.*—Eight cerebral hemispheres examined.

In one, . .	Insula perfectly smooth (Pl. IV., fig. 8).
In one, . .	Sulcus centralis Reillii alone very feebly marked.
In four, . .	Two furrows, viz. the sulcus centralis and sulcus postcentralis.
In two, . .	Three furrows, viz. the præcentralis, centralis, and postcentralis.

III. *Hamadryas.*—Two hemispheres examined.

In one, . .	Two furrows, viz. the sulcus centralis and postcentralis.
In one, . .	Three furrows, viz. the sulcus præcentralis, the sulcus centralis, and the sulcus postcentralis.

IV. *Cercopithecus.*—Four hemispheres examined.

In one, . .	One furrow, the sulcus centralis.
In three, . .	Two furrows, the sulcus centralis and the sulcus postcentralis.

V. *Mangaby.*—Four hemispheres examined.

In three, . .	One furrow, the postcentral.
In one, . .	Two furrows, the central and the postcentral.

VI. *Cebus.*—Five hemispheres examined.

In two, . .	Insula smooth.
In two, . .	One furrow, the central.
In one, . .	Two furrows, the central and the postcentral.

From the foregoing it is, therefore, very evident that the most usual condition of the insula in the lower ape is that in which it presents a central and a postcentral furrow, with the three corresponding gyri. The latter are very feebly developed. With the exception of the cebus, a gyrus transversus can be detected in almost every case.

But another very striking difference between the human cerebrum and the cerebrum of the ape is to be found in the relative size and position of the submerged portion of the island of Reil. If we take the

lateral length of the hemisphere as being equal to 100, the following Table gives the percentage of this, which is formed by the insula, as well as of the portions of cerebrum in front and behind. The measurements were made in precisely the same manner as that adopted for the human brain :—

RELATIVE LENGTH OF THE SUBMERGED PART OF THE INSULA IN MAN AND THE ANTHROPOID APES.

Lateral length of the Hemisphere = 100.

	Number of Hemispheres Examined.	Fronto-Central Index.	Central Index.	Occipito-Central Index.
European, ...	28	26·3	29·6	44·1
Orang, ...	2	32·2	21·5	46·3
Chimpanzee, ...	4	34·1	18·2	47·7

No one who handles the brain of an anthropoid ape can fail to see that the submerged part of the insula is relatively smaller than the insula in the brain of man, but I was certainly not prepared to find the marked difference which is brought out by the above Table. It is in the fore-part that it chiefly fails. In the chimpanzee, the distance at which the so-called anterior limiting sulcus is situated from the fore-end of the cerebrum is expressed by the index 34·1, and in the orang by the index of 32·2. In the European the corresponding index is only 26·3. Our examination of the gyri on the surface of the anthropoid insula, as we have already noted, afforded results which are altogether in keeping with these measurements. At the same time it will be observed that in neither the chimpanzee nor in the orang does the island of Reil extend so far backwards. The difference in this respect, however, is not great.

The size of the island of Reil, which may be regarded as the surface expression of the magnitude of the subjacent lenticular nucleus, &c., exercises a marked influence on the configuration of the fore-part of the cerebral hemisphere. Indeed I believe that the difference in the dimensions of the insula and the lenticular nucleus in man and the ape is in some

measure at least responsible for the difference in the shape of the human and the anthropoid frontal lobes.

In the lower apes the long axis of the insula in comparison with the lateral length of the cerebrum is relatively greater than in the anthropoid apes. This does not necessarily mean that there is a more extensive insular area in the lower apes, seeing that the measurements were only taken with reference to the length of the island. As is well known, the island of Reil in the lower apes is very narrow. The following Table gives the results of these measurements expressed in indices which correspond with those in the preceding Table :—

Relative Length of the Long Axis of the Insula in the Lower Apes.

Lateral Length of the Hemisphere = 100.

Ape.	Number of Hemispheres Examined.	Fronto-Central Index.	Central Index.	Occipito-Central Index.
Cebus, ...	6	31·5	26·7	41·8
Cercopithecus, ...	2	31·4	24·9	43·8
Macaque, ...	6	29·8	24·9	45·3
Mangaby, ...	6	31·3	25·3	43·4
Cynocephalus, ...	8	30	27·9	42·1
Hamadryas, ...	2	32·8	23·9	43·3

If we compare these indices with those obtained for the anthropoid apes, it will be seen that the greater length of the insula in the low apes is chiefly due to a closer approach of its posterior end to the occipital extremity of the cerebrum. This is particularly noticeable in the cebus and the baboon, in which the posterior end of the insula is placed relatively nearer the occipital pole than in man.

VIII. **Relation of the Island of Reil to the Cranial Wall.**—We have studied the position of the insula with reference to the anterior and

posterior ends of the hemisphere, and noted marked differences in this respect in the brain of man, the anthropoid apes, and the lower apes. There is an equally sharp distinction to be observed when we study its position with reference to the cranial wall.

In the adult human brain the insula lies under cover of the frontal, parietal, squamo-zygomatic, and alisphenoid bones. If we take the line of the coronal suture we find that 13 per cent. of its long axis lies in front of this, and 87 per cent. behind. Very different is the condition in the ape. In cebus the insula is placed entirely under cover of the anterior and lower part of the parietal bone. The coronal suture coincides with its anterior extremity. In the chimpanzee (Pl. IV., fig. 9, the dotted line indicates the position of the coronal suture) and all the low old world apes (Pl. IV., fig. 8, the dotted line indicates the position of the coronal suture) which I have examined the submerged portion of the insula is also for the most part covered by the lower and fore-part of the parietal bone, but it also extends downwards so as to lie partially under cover of the squamous bone. As in cebus the coronal suture corresponds more or less accurately with the anterior limit of the insula. The orang approaches most nearly to man in the cranial relations of the island of Reil. The upper and anterior corner of the insula projects very slightly beyond the coronal suture (Pl. IV., fig. 11), but with this exception the remainder of the area is placed under cover of the parietal and squamous bones.

But, as we might expect from what we have learned in regard to the manner in which the insula extends backwards in the fœtal brain, we find that during the early stages of the growth of the brain the cranial relations of the island of Reil undergo very striking changes. In its very early condition there is a greater part of the Sylvian fossa under cover of the frontal bone than under cover of the parietal bone. Its relations to the cranial wall at successive periods will be better understood if we take the long axis of the area as being equal to 100 and divide this into two parts—an anterior and a posterior—by the line of the coronal suture drawn downwards so as to cross it. The following Table gives the results obtained in this way :—

Relation of the Insula to the Coronal Line.

Long axis of the Insula = 100.

Period of Growth.	Number of Hemispheres Examined.	Part of Insula in front of Coronal Line.	Part of Insula behind the Coronal Line.
4 to 5 months, ...	3	48·3	51·7
5 to 6 months, ...	7	39·7	60·3
6½ months, ...	2	37·2	62·8
7 to 8 months, ...	2	34·6	65·4
8 to 9 months, ...	2	32·9	67·1
Adults, ...	4	13	87

The steady increase of the portion of the insula which lies behind the coronal line and the corresponding relative decrease of the part which lies

Fig. 28.—Lateral view of the skull of a child about nine months old. The internal sutural lines are brought out on the surface by a series of perforations made from the interior. They can therefore be compared with the external sutural lines

in front of this line is of course chiefly due to the manner in which the Sylvian area extends by backward growth. But this does not account for

all the change that occurs. The coronal line is by no means fixed. In its early condition the field of the parietal bone in the antero-posterior direction is relatively less than in the adult, and by its subsequent growth forwards it comes to cover a relatively greater part of the island of Reil. This is particularly noticeable in connexion with the lower fifth of the coronal suture. Here the anterior border of the parietal bone in the process of cranial growth sends forward a squamous portion which gradually overlaps the corresponding portion of the posterior border of the frontal bone. This is rendered evident in the four skulls which are figured in

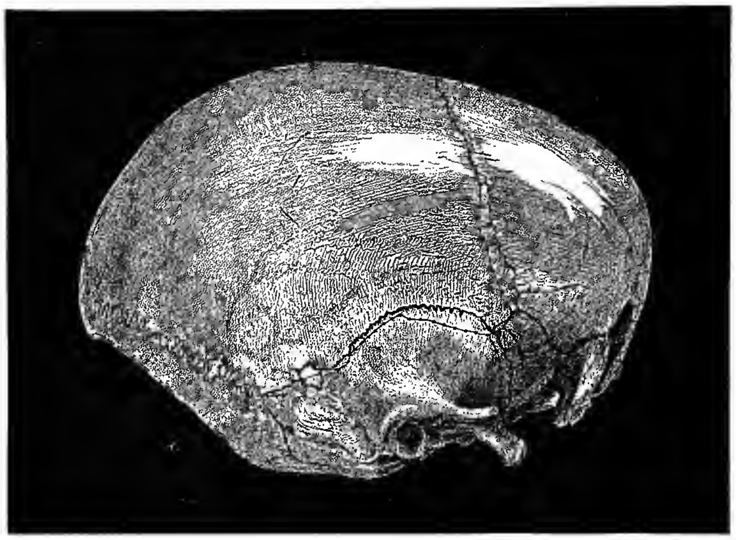


Fig. 29.—Lateral view of the skull of a child about fifteen months old. The internal sutural lines are shown by a series of perforations made from the interior. They can be compared with the external sutural lines.

pages 119–122. In these the cranial wall has been drilled along the lines of the sutures as these are seen on the interior of the cranium. By this means the posterior border of the frontal bone is delineated on the outside of the different skulls, and it will be noticed that as the period of childhood gives place to that of full growth the overlapping process of the parietal bone increases in extent and carries forward the lower part of the external coronal line; and it can be easily proved by measurements of the cranium

that during this process, the frontal bone, to all intents and purposes, remains passive. In other words, the overlapping is not brought about by a backward growth of the posterior edge of the frontal bone: indeed the measurements which I have made would rather seem to indicate that in its lower part the area of the frontal bone is, if anything, more extensive in the child than in the adult.

The extent of the overlapping squamous portion of the parietal bone varies very greatly in different skulls, and thus it arises that the relation of

Fig. 30.—Lateral view of the skull of a child about six years old. The cranial wall has been drilled from the interior along the internal sutural lines. These can therefore be compared with the external sutural lines.

the external coronal line to the insula is by no means the same in all adult heads. Probably the figures which are given convey a tolerably accurate estimate of the average condition, but I have seen one head in which the coronal suture very nearly coincided with the anterior end of the insula, and another in which 24·6 per cent. of the length of the insula lay in front of the suture.

It is interesting to observe that the external coronal line corresponds

very accurately in the fœtus with the sulcus præcentralis Reillii of the insula.

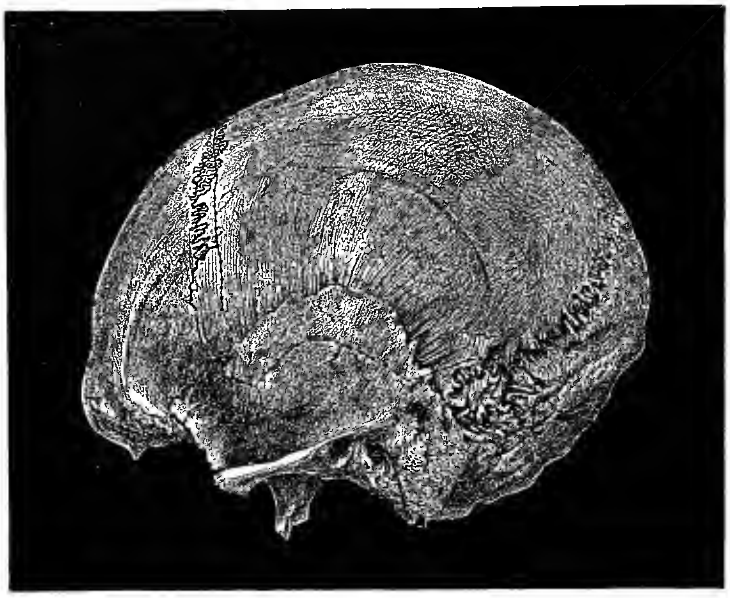


Fig. 31.—The lateral view of an adult skull. The cranial wall has been drilled along the internal sutural lines. These can therefore be compared with the external sutural lines. The extent to which the squamous projections of the temporal, alisphenoid and parietal bones overlap the margins of the contiguous bones is seen.

IX. **Sylvian Point.**—The point at which the trunk of the Sylvian fissure appears on the outer surface of the cerebral hemisphere may be termed the "*Sylvian Point.*" The relative position of this point is very different in the brain of man and in the brain of the ape. It was found to vary also to a considerable extent in the different apes examined. In the following Table the lateral length of the hemisphere is taken as 100, and the figures given indicate the position of the Sylvian Point with reference to the anterior end of the cerebrum. In the human brain the "Sylvian Point" is placed relatively further forwards upon the side of the cerebral hemisphere than in the ape's brain. In the European brain the fronto-Sylvian index is 32·7, whereas in the orang and the majority of the other apes examined it is rather more than 34. It is important to note that in

certain of the apes the index is still higher; thus in the mangaby, chimpanzee, and hamadryas it varies from 36·2 to 37·2:—

Relative Position of the "Sylvian Point" with reference to the Anterior End of the Cerebrum in Man and the Ape.

Lateral Length of the Hemisphere = 100.

—	Number of Hemispheres Examined.	Fronto-Sylvian Index.
European (Adult),	53	32·7
Negro,	5	34·5
Orang,	2	34·2
Cebus,	6	34·5
Cynocephalus,	7	34·4
Macaque,	5	34·5
Mangaby,	6	36·2
Chimpanzee,	4	36·4
Hamadryas,	2	37·2

I do not lay much stress upon the high fronto-Sylvian index obtained for the five negro brains. As I have previously explained, the negro brains in my possession were hardened on the west coast of Africa with no special precautions for the preservation of the true form, and although I have only measured those which appear to have suffered the least amount of distortion, I cannot attach much importance to the results obtained.

But the position of the "Sylvian Point" varies somewhat in the human brain at different periods of growth. It makes a slight advance forwards as growth progresses, and it may be said to become finally fixed in its position between the fifth and the eleventh year. The following Table makes this clear:—

Relative Position of the "Sylvian Point" with reference to the Anterior End of the Cerebrum at different periods of the growth.

Lateral Length of the Hemisphere = 100.

Period of Growth.	Number of Hemispheres Examined.	Fronto-Sylvian Index.
Adults, ...	53	32·7
11 to 15 years, ...	6	32·1
4 to 5 years, ...	7	34·9
1 year, ...	8	33·1
Full-time fœtuses, ...	11	33·7
$7\frac{1}{2}$ to $8\frac{1}{2}$ months, ...	12	35·2

There is apparently no difference in the relative position of the "Sylvian Point" in the right and left hemispheres of the human brain. Twenty-eight adult right hemispheres gave a fronto-Sylvian index of 32·7; whereas twenty-five adult left hemispheres afforded an index of 32·8.

In the male, however, the "Sylvian Point" would appear to be placed slightly in front of the same point in the female, and this is a distinction which can be made out not only in the adult but also in the earlier stages. The following are the detailed results:—

Position of the "Sylvian Point" with reference to the Anterior End of the Cerebrum in the Male and Female.

Lateral Length of Hemisphere = 100.

Period of Growth.	Number of Hemispheres Examined.		Fronto-Sylvian Index.	
	Males.	Females.	Males.	Females.
Adults, ...	31	22	32·4	33·2
11 to 15 years, ...	4	2	31·9	33·1
4 to 5 years, ...	5	2	34·4	36
1 year, ...	2	6	33·3	33·1
Full-time fœtuses, ...	9	2	33·5	34·7

In the early periods of growth and in the female the "Sylvian Point" in the human brain is therefore placed slightly further back than in the case of the adult and the male. In this respect the female exhibits the retention of an infantile character, and shows a slight approach to the condition present in the ape.

X. **The length of the posterior horizontal limb of the Sylvian Fissure.**—Eberstaller of Graz is the only anatomist who has sought to determine with any degree of care the average length of the posterior horizontal limb of the Sylvian fissure. It is somewhat difficult to fix upon two points which can be accurately determined on every hemisphere between which the measurements may be made. Posteriorly the fissure almost invariably ends by bending suddenly upwards into the parietal lobe, and in many cases it likewise sends downwards from the same point a short descending branch. These terminal pieces have been distinguished as the ramus posterior ascendens and the ramus posterior descendens. Eberstaller, in his measurements, assumed as the posterior end of the fissure the angle which the ramus posterior ascendens forms with the main stem. In those cases where this point was not sufficiently well-marked, he called to his aid the ramus posterior descendens, and by a study of both he fixed the posterior end of the fissure. In front he selected the point of junction between the ramus horizontalis anterior and the ramus horizontalis posterior or in cases where there was only one anterior limb the point of union between this and the posterior limb.

Eberstaller conducted his measurements with very great care, and with every precaution towards the acquisition of reliable results. The fresh cerebrum was extracted from the cranial cavity by cutting through the mesencephalon. By a mesial incision the two hemispheres were set free, and immersed in a water-bath, so that the natural configuration might be as far as possible retained. The membranes were removed, and the measurements made by means of a pair of compasses.

The first results which Eberstaller* published on this question were

* Zur Oberflächen-Anatomie der Grosshirn-Hemisphären.—Vorläufige Mittheilung.—Das untere Scheitelläppchen.—Wiener Medizinische Blätter, No. 21. 1884.

obtained from the measurement of sixty-four brains (thirty-two male, thirty-two female). More recently, however, he has given us the results of a very much more extended inquiry in which he has measured nearly four hundred hemispheres.* He has come to the conclusion that the Sylvian fissure is, on an average, longer in the left hemisphere than in the right, and, further, that it is longer in the male than in the female. It will be necessary to study his data somewhat in detail. He states that the posterior horizontal limb of the Sylvian fissure "in one hundred and seventy left hemispheres presented an average length of 58·2 mm.; in one hundred and eighty-three right hemispheres an average length of 51·8 mm. The difference in favour of the left side is therefore, on an average, 6·5 mm. Still these results will be more apparent if I add that in one hundred hemispheres the following lengths occurred:—

Under and up to 50 mm., . . .	Left, 22 times;	right, 45 times.
From 51 to 60 mm., ...	,, 42 ,,	,, 44 ,,
From 61 to 70 mm., . . .	,, 27 ,,	,, 11 ,,
Over 70 mm., ...	,, 9 ,,	,, 0·6 ,,

Whilst, therefore, the great majority (nine-tenths) on the right side presented a length under 60 mm., a full third on the left side overstepped this length."

In this investigation, Eberstaller only deals with the absolute length of the fissure as he observed it in the two hemispheres, and, although the results which he lays before us are very striking, it would have been more satisfactory had he given us the means of studying the relative length of the fissure on the two sides. It is generally understood that the left hemisphere presents an average length which is slightly greater than that of the right hemisphere, and it would be reasonable to suppose that the absolute length of the Sylvian fissure on the left side would, in correspondence with this, be greater than that of the right side. It is true, the great average difference between the two fissures of 6·5 mm. could hardly be accounted for in this manner, but this does not lessen the necessity of our obtaining relative as well as absolute results.

* Das Stirnhirn. Wien und Leipzig, 1890.

In my measurements I have fixed the limits of the posterior horizontal limb very much in the same way as Eberstaller. I have adopted the same posterior limit, but in front I have always measured from the "Sylvian Point." The origin of the single anterior limb of the Sylvian fissure, when this exists alone, and of the anterior horizontal limb, when the two front rami are present, cannot be relied upon as giving us, in every case, precisely the same point. In calculating the relative length of the fissure from the absolute measurement, I have reckoned the lateral length of the hemisphere as being equal to one hundred: a length index for the Sylvian fissure is thus obtained. The following Table gives these indices for the two sides of the human brain at different periods of growth :—

Length Index of the Sylvian Fissure at different Periods of Growth and on the two Sides.

Lateral Length of Hemisphere = 100.

Number of Hemispheres Examined.	Period of Growth.	General Index for both sides.	Index for the Right Side.	Index for the Left Side.
53 (28 right, 23 left), .	Adult, . .	26·1	24·4	28
6 (3 right, 3 left), .	11 to 15 years, .	25·8	25·8	25·8
7 (3 right, 4 left), .	4 to 5 years, .	24·5	22·7	26
8 (5 right, 3 left), .	First year, . .	25	23·2	26·1
11 (6 right, 5 left), .	Full-time fœtuses,	28·4	27·8	29·2
12 (6 right, 6 left), .	7½ to 8½ months, .	28	27	29

By these figures Eberstaller's assertion that the left fissure of Sylvius is longer than the right is borne out in the fullest manner, and it will be seen that this distinction is not confined to the adult brain, but is evident at all periods of growth. In the early stages, however, the difference is not so marked, and it is in the adult brain that it attains its full accentuation.

We have seen that the insula on the left side is relatively longer than the corresponding area on the right side, and the question, therefore,

naturally arises: Is this difference in the size of the two insulæ not the cause of the difference in the length of the two posterior horizontal limbs of the Sylvian fissures? My own belief is that it is not, because, as we shall see later on, a similar difference in the size of the insula in the two sexes is not followed by a corresponding difference in the length of the fissure in the male and female; and, further, the fissure in the ape is relatively much longer than in man, and yet the insula is shorter. The cause is to be looked for in the condition of the transverse temporal convolutions of Heschl, and also of the arching convolutions which connect the supramarginal and angular gyri with the upper two convolution-tiers of the temporal lobe. We shall require to return to this question when we have fully studied all the facts in connexion with the varying length of the fissure.

But the Table which I have given of the length-indices of the Sylvian fissure show that the posterior horizontal ramus does not possess the same relative length at all periods of growth. In the full-time fœtus, and in the immature fœtus of from seven and a-half to eight and a-half months the fissure is relatively longer than in the adult. In the intermediate stages it would appear to be relatively shorter.

As we have mentioned, Eberstaller also maintains that the fissure of Sylvius is on an average longer in the female than in the male. "Die Differenz, 2·5 mm.," he remarks, "ist an sich nicht grossund würde kaum beachtenswerth sein, gewänne sie an Bedeutung nicht durch die bekannte Thatsache, dass das Weiberhirn als Ganzes genommen kleiner ist, als das Männerhirn, daher viel eher das Gegentheil zu erwarten war."

The results which I have obtained from measurements of the Sylvian fissure do not give support to this statement by Eberstaller. In fact what difference there is I have found in favour of the male. Taking the lateral length of the hemisphere as 100, 31 male hemispheres yielded an average length-index of the Sylvian fissure of 26·8; whilst 22 female hemispheres gave an index of 25. It must be noted, however, that although Eberstaller only gives the average absolute length of the fissure in the two sexes, he measured a much larger number of hemispheres, viz. 81 female and 272 male. The question certainly requires further investigation, and it should

be borne in mind that the Sylvian Point in the female is placed relatively further back than in the male.

For purposes of comparison I have also measured the Sylvian fissure in a number of ape brains. In the lower apes the measurements were made from the "Sylvian Point" to the extremity of the fissure where this ends on the surface, or up to the submerged supramarginal convolution in cases where the Sylvian fissure enters into superficial connexion with the parallel sulcus. The lateral length of the hemisphere was reckoned as 100, and the length-index of the fissure calculated accordingly :—

Length Index of the Fissure of Sylvius in the Apes.

Lateral Length of Hemisphere = 100.

Ape.	Number of Hemispheres Examined.	General Index for all.	Index for Right Side.	Index for Left Side.
Chimpanzee, . .	4 (2 right and 2 left), .	30·2	28·8	31·6
Orang, . . .	2 (1 right and 1 left), .	35	35·7	34·4
Mangaby, . .	6 (3 right and 3 left), .	35·4	35·5	35·4
Cynocephalus, . .	7 (4 right and 3 left), .	38·1	37·5	38·9
Macaque, . .	5 (3 right and 2 left), .	38·7	37·2	40·4
Hamadryas, . .	2 (1 right and 1 left), .	39·2	—	—
Cebus, . . .	6 (3 right and 3 left), .	37·7	38·7	36·8

The greater relative length of the fissure in the ape is made very evident by this Table, and it is interesting to observe, although the number of hemispheres examined is too small to decide the point, that in the greater number of the varieties examined the left fissure is relatively longer than the right.

The greater relative length of the fissure in the ape is partly due to the fact that in man we have not included in the measurements the ramus posterior ascendens. But this is not the sole cause. The decrease in the length of the Sylvian fissure in man is largely brought about by an increase in the size of the arching convolutions which connect the supramarginal

and the angular gyri of the parietal lobe with the two upper convolutions of the temporal lobe. These arching gyri bear a very close connexion with the transverse convolutions of Heschl which appear on the deep surface of the temporal operculum. Eberstaller has very properly called attention to this. He says: "Just as the inferior parietal lobule in the lower apes presents a single weak arching convolution, the gyrus angularis, bent around the upper end of the parallel fissure, whilst the gyrus supramarginalis which closes the end of the Sylvian fissure still lies concealed as a deep gyrus within it, only to come to the surface in the higher apes, so there is also found in these higher apes and in man, going hand in hand with the development of the temporal lobe, several hidden gyri in the Sylvian fissure, which shorten the Sylvian fissure and increase the cortical district of that region in which we have to seek the *sensible Sprachcentrum*."

In well-marked cases the transverse gyri of Heschl are arranged in the human brain one behind the other in the form of a series of steps and stairs which gradually lead to the surface. Further, it is no uncommon thing to find that the hindmost of these gyri has completely reached the surface and has ranged itself in front of the supramarginal convolution. To one who studies the development of the Sylvian region the explanation of this is simple. In its early condition the Sylvian fossa is surrounded by steep perpendicular banks which ultimately form the lips of the different opercula. The posterior rounded angle of the region, however, ascends with a gradual and easy inclination towards the surface of the cerebral mantle, so that in many cases it is exceedingly difficult to fix accurately at this stage the posterior end of the insula (Pl. II., figs. 12 to 15). It is upon the surface of this inclined plane that the transverse gyri of Heschl are formed, but the process is hidden from view by the meeting of the parietal and temporal opercula over them. The anterior gyrus of Heschl appears first (about the beginning of the seventh month, Pl. II., figs. 20 and 21, *h*), and the others assume shape in regular order from before backwards.

Sometimes there seems to be a secondary forward growth of this part of the cortex which leads to a very decided shortening of the Sylvian fissure. In fact, in these cases the fissure may fall short of the posterior

extremity of the insula. This produces an undermining of the cerebral mantle by the hinder end of the island of Reil.

I have noted the condition of the transverse gyri of Heschl in 73 hemispheres, and have found that in 2·8 per cent. only one was present; in 20·5 per cent. two; in 56·1 per cent. three; in 19·2 per cent. four; and in 1·4 per cent. five. Two other points of some importance were established: (1) It is more usual for the hindmost gyrus to reach the surface on the right side than on the left; and (2) in those hemispheres in which four gyri were present, 28·6 per cent. only belonged to the right side, whilst 71·4 per cent. belonged to the left side.

In the anthropoid ape there are two, and in many cases three transverse temporal gyri of Heschl, but these are feeble and resemble the corresponding gyri in the human brain in the early stages of their development (Pl. IV., figs. 9 and 11). Further, the anterior gyrus does not stand out so prominently from the others as in the case of the human brain.

In the lower apes it is usual to find only one transverse temporal gyrus of Heschl, and with it the supramarginal convolution is, as a rule, concealed within the Sylvian fissure. This is the condition present in cebus. In the baboon the supramarginal convolution is more usually on the surface. Thus in ten hemispheres it was superficial in seven, and depressed within the fissure in three. In rare cases also a second transverse gyrus of Heschl may be noted in the baboon. In the mangaby the supramarginal convolution is usually deep and hidden from view. In two out of seven hemispheres I found it superficial. In all cases only one gyrus of Heschl was present.

XI. **The Angle of the Sylvian Fissure.**—By this I mean the angle which is formed by the posterior horizontal limb of the Sylvian fissure with a line drawn at right angles to the longest antero-posterior diameter of the hemisphere. For the purpose of measuring this angle I had a special instrument constructed. Two straight, narrow, and flexible bands of brass, measuring 12 inches and 18 inches respectively, were prepared. These were jointed together by a pin which fixed the extremity of the short band

to the centre of the long band, and in such a way that the free extremity of the former could be approximated towards or carried away from either end of the latter. When the measurement had to be conducted on the brain *in situ* a thread was tied horizontally round the head so as to pass round the most projecting point of the frontal and the most prominent point of the occipital lobe. This constituted the base line, and the long band of the instrument was then placed at right angles to this line, and moved until the joint between the two limbs came to lie immediately under the Sylvian Point. It was then bent round the head, and secured in this position while the short metal band was moved upwards and downwards, until its upper border was found to coincide with the general direction of the Sylvian fissure.

In dealing with hemispheres which were removed from the cranial cavity a different plan was pursued. A rectangular sheet of glass, 18 inches long and 6 inches wide, was bisected by two straight lines cut by

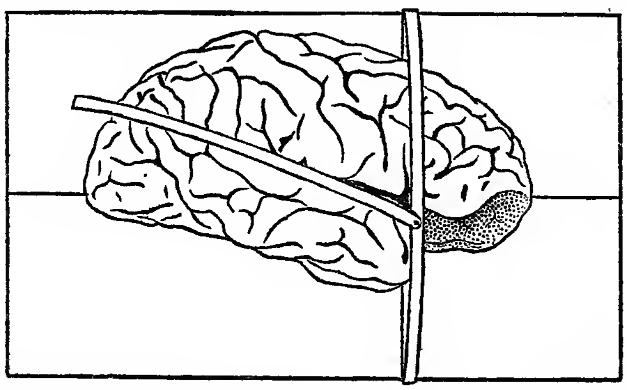


FIG. 32.—Method of ascertaining the angle of the Fissure of Sylvius in a cerebral hemisphere removed from the cranial cavity.

a diamond, first in the longitudinal direction and then in the transverse direction. These lines intersected each other at right angles. The cerebral hemisphere was placed with its mesial surface in contact with the glass. It was then carefully adjusted, so that the longitudinal line accurately corresponded with its longest antero-posterior diameter, while the transverse line intersected the Sylvian Point. The metal instrument was applied to the brain, as before—the long limb being bent round

the outer surface of the brain, in a direction corresponding to the transverse line on the glass, and the joint being placed just below the Sylvian Point. The short metal band was then moved into the line of the fissure (fig. 32). The angle obtained in this way by the instrument, was traced on paper, and measured in the ordinary way.

Sylvian Angle in Man.

Period of Growth.	Number of Hemispheres Examined.		Average Angle.	Right.	Left.
	Right.	Left.			
Adults,	16	15	67°·8	66°·3	70°·3
11 to 15 years,	6	4	65°·8	62°·	71°·7
4 to 5 years,	4	4	64°·1	61°·2	67°·
First year,	4	2	67°·2	66°·5	69°·
Full-time fœtuses,	5	4	62°·1	60°·5	64°·
7½ to 8½ months,	6	6	61°·5	57°·3	64°·8

In the adult the average angle is 67°·8, and there appears to be no difference in this respect between the male and the female. In the former I obtained an average angle of 67°·9, and in the latter an average angle of 67°·7. The angle, however, is subject to very great variations in individual cases. Thus, in one female hemisphere the angle was 54°, whilst in four hemispheres (three males and one female) it was 74°.

But a further examination of the above Table makes it evident that the angle is not of equal magnitude at all stages of growth, and also that it differs considerably in the right and left hemisphere. In the early condition of the brain the angle is much more acute, but as growth advances the posterior part of the fissure becomes more depressed, and the angle, in consequence, opens out. This is apparently due to the fact that the fronto-parietal operculum continues to grow downwards even after the insula is closed in and its margin has met the temporal operculum.

The greater angle on the left side is evident at every stage of growth, and constitutes a marked difference between the two hemispheres.

Calori,* Meyer,† and Rudinger,‡ have shown that the form of the head exercises a very marked influence upon the direction of the fissures and convolutions on the surface of the cerebrum. In sixteen cases in which the angle of the Sylvian fissure was measured, the cephalic index was also ascertained. A comparison of this with the angle has led me to believe that the direction of the Sylvian fissure is little influenced by the configuration of the cranium. We shall classify the results into two groups, according to the cephalic index. Into the one group we shall place those which present an index of 77 and under; in the second group we shall place those in which the cephalic index is 78 and upwards. In this way we shall the better see the relationship which exists between the cephalic index and the Sylvian angle.

Relation between the Form of the Head and the Sylvian Angle.

Group I. Cephalic Index 77 and less.		Group II. Cephalic Index 78 and upwards.	
Cephalic Index.	Sylvian Angle.	Cephalic Index.	Sylvian Angle.
77	70°	80·7	67°
76·2	72°	80	70°
75·2	54°	79·2	65°
75·1	62°	79	65°
75	63°	79·2	72°
74·1	67°	78·3	66°
74	72°	78·2	67°
74	72°	78	65°
Average, 75	66°·5	79	67°·1

* "Del cervello nei due tipi brachicephalo e dolicocephalo Italiani," Memorie dell' Accad. delle Sc. di Bologna, 2. ser. t. x., Fasc. 1. 1871.

† "Ueber den Einfluss der Schädelform auf die Richtung der Grosshirnwindungen," Centralblatt für die medicinischen Wissenschaften. Oct. 21, 1876, No. 43.

‡ Ueber die Unterschiede der Grosshirnwindungen nach dem Geschlecht beim Fötus und Neugeborenen. München, 1877.

From this Table we see that eight heads, with an average breadth-index of 75, give an average Sylvian angle of 66°·5; whilst an equal number of heads, with an average breadth-index of 79, furnish us with an average Sylvian angle of 67°. The difference in the angle in the two groups is so slight that we need not take it into account. The same will be seen if we study the individual cases. In fact, no law can be formulated from the results. The Sylvian fissure, therefore, must be placed on a different platform from the other fissures of the cerebrum. It is altogether different in its mode of formation, and, unlike them, it does not seem to be affected in its inclination by the shape assumed by the cranium. The influence chiefly concerned in determining its direction is probably the growth energy of the two opercula between which it intervenes.

The following Table gives the Sylvian angle as it has been observed in the apes:—

Sylvian Angle in the Apes.

Ape.	Number of Hemispheres Examined.	Average Angle.	Right.	Left.
Chimpanzee, ...	4	54°·5	52°·5	56°·5
Orang, ...	2	55°	54°	56°
Cebus, ...	6	54°·1	53°·3	55°·
Mangaby, ...	4	49°·2	48°	50°·5
Baboon, ...	7	48°·6	48°	49°·3
Macaque, ...	5	46°·5	47°·3	45°
Hamadryas, ...	2	44°	41°	47°

In the ape the angle is very much more acute than in man, and a considerable amount of variation exists between the different forms. It is interesting to note that with the exception of one form (macaque) all the apes show a wider Sylvian angle on the left side than on the right side. We have observed the same difference in man. I am quite unable to explain this curious difference. Can it be due to a greater development on

the left side of that part of the cortex in which the motor centres reside? Had it only been evident in man, I should have been inclined to associate it with right-handedness.

XII. **Topography of the Sylvian Fissure in Man.**—It is well known that the posterior horizontal limb of the fissure of Sylvius, when first formed by the apposition of the temporal and fronto-parietal opercula, and also in the first few years of childhood, lies considerably above the level of the squamous suture. Foulhouze, in a Thesis* prepared under the direction of Broca, and published in 1876, was the first who clearly established this point. In the same field of work he has been followed by Féré,† Merkel,‡ and Symington.§

Foulhouze determined the position of the sulci on the young brain by the method which was first employed by Broca in the case of the adult brain. He introduced pegs through the cranial wall, and then removed the brain. The soft yielding brain of an infant is not suited for this procedure, and accurate results could hardly be expected from it. Foulhouze gives us merely absolute measurements, and his results may be summarized as follows:—

Distance of the Fissure of Sylvius above the Squamo-parietal Suture.

(1.) Four infants in the first month of extra-uterine life,	average,	11·5 mm.
(2.) One infant, 4 to 5 months,		14 mm.
(3.) Nine infants, from 18 months to 3 years,	average,	12·11 mm.
(4.) One child, 5 years,		8 mm.
(5.) One girl, 13 years,		6 mm.

Foulhouze adds two diagrams which are intended to show the relations of the cerebrum to the surface of the cranium in an infant of eight days, and in a child of two years. These are far from accurate, and the inferior

* Recherches sur les rapports anatomiques du cerveau avec la voute du crane chez les enfants. Paris, 1876.

† "Sur le développement du cerveau considéré dans ses rapports avec le crane," Revue d'Anthrop., 1879.

‡ Handbuch der topographischen Anatomie. 1885.

§ Topographical anatomy of the Child. Edinburgh, 1887.

border of the hemisphere is represented by a dotted line, which conveys an altogether erroneous impression of its relations.

Féré adopted a more satisfactory method (see Introductory Chapter), and conducted his observations on the brain while still within the cranial cavity. Further he pushed his inquiries into the intrauterine stages of cerebral growth. Unfortunately, he also only gives absolute measurements. The following is a short summary of his results:—

Distance of the Fissure of Sylvius above the Squamo-parietal Suture.

(1.) Four seven-months' fœtuses,	average,	6 mm.
(2.) One fœtus, 8½ months,		10 mm.
(3.) Twenty-three infants in the first month,	15 males, average,	18 mm.
	8 females, ,,	16 mm.
(4.) Seven infants of from one to two months,	,,	19 mm.
(5.) Three boys, between 6 and 7 months,		18 mm.
(6.) Two children, 1 year old,		16·5 mm.
(7.) One child, 3½ years,		16 mm.
(8.) One child, 4 years 9 months,		6 mm.

There is a considerable difference between the results obtained by Foulhouze and Féré. This is, no doubt, due to the mode of procedure adopted by the former observer. Féré's results may be regarded as the more reliable. They are very nearly in accord with the measurements I have made at corresponding periods of growth.

Merkel furnishes us with a good drawing of the cranio-cerebral relations in a new-born child, but he falls into the same error as Foulhouze in the delineation of the lower border of the cerebrum. The infero-lateral border of the temporal lobe he depicts on the same level as the superciliary border of the frontal lobe, and, consequently, he places the lower border of the former lobe high above the zygoma.

Symington, as we have seen, adopted a very satisfactory mode of procedure (see Introductory Chapter). He examined the relations of the Sylvian fissure in several fœtuses, and in children up to the age of six years. "In all of these the fissure was covered by the parietal bone, and lay some distance above the anterior part of the squamous suture." In a new-born child it was 10 mm. above the suture on the left side, and 12 mm.

above the suture on the right side. In a child two years and two months old the fissure was 14 mm. above the suture. Symington is of opinion that the fissure and the suture "begin to approach each other soon after the end of the second year, and that they gain their permanent positions by the eighth or ninth year. Thus, in a well-developed boy, five years old, the fissure was only about 5 mm. above the anterior part of the suture, while in a girl, nine years of age, they were practically at the same level." He believes, however, that the process may be delayed.

In the main we may consider that the conclusions which have been arrived at by Symington are correct, but it must be noted that the process is one which is subject to great variation. In Plates v. and vi. the relations which are presented by the Sylvian fissure and the squamo-parietal suture are exhibited in a series of heads at different periods of growth. If we compare figure 5, which represents the head of a girl six months old, with figure 4, the head of a girl one year old, we observe that in the older specimen the distance between the suture and the fissure is both relatively and absolutely greater than in the younger specimen. In the former it is 21 mm., whilst in the latter it is 16 mm. Again, in figures 6 and 7 are exhibited the heads of a girl and a boy of four years old. In the former the fissure has nearly attained the adult position with reference to the suture, being only 4 mm. above it, whilst in the latter it is still 14 mm. distant from it. Again, little progress is shown in figure 8, a boy of five years old, where the suture is still 14 mm. below the fissure. Then when we come to figures 9, 10, and 11, which are drawings of the heads of a girl of eleven, a boy of twelve and a-half, and a youth of fifteen, we reach a condition which is very common in the adult. Still it is noteworthy that in all of these the fissure is still above the level of the suture, whilst in the adult we may meet with it above, subjacent to, or below the suture.

But all conclusions which rest simply upon absolute results are unsatisfactory. We can only obtain a proper conception of the true position of the Sylvian fissure and of the changes which this undergoes on the surface of the cerebrum, and in reference to the cranial wall by the conversion of absolute into relative results. The relative position which the Sylvian fissure occupies at different periods of life has not hitherto been determined.

We must endeavour therefore to ascertain:—

1. The relative position of the Sylvian fissure with reference to the squamo-parietal suture.

2. The relative position of the fissure with reference to the mesial and infero-lateral borders of the hemisphere.

Further, in making our measurements it is essential in every case to follow precisely the same line. The following is the plan which I have adopted:—I have taken the longest antero-posterior axis of the cerebrum as a base-line, and from this I have let drop a perpendicular which cuts through the inferior end of the ascending parietal convolution. Such a line when carried upwards usually cuts the mesial border of the hemisphere immediately in front of the ascending frontal convolution, whilst below, if prolonged beyond the brain, it would reach the anterior border of the external auditory meatus. All my measurements between points on the surface of the brain have been made along this vertical line. In estimating the distance between the squamo-parietal suture and the Sylvian fissure, however, I found it impossible to adhere rigorously to such a line. In this instance, therefore, I have always measured the distance of the fissure from the highest point of the suture.

Where the measurements were made upon hemispheres removed from the cranial cavity use was made of the sheet of glass already referred to in connexion with the determination of the Sylvian angle. The cerebral hemisphere was placed with its mesial surface downwards on the glass, and adjusted so that the longitudinal line corresponded with its antero-posterior axis, and the vertical line cut the mesial border of the hemisphere just in front of the ascending frontal convolution. The outer surface of the specimen was then measured in the direction of the latter line.

The measurements were made with the tape. We shall distinguish the entire measurement from the mesial to the infero-lateral margin of the hemisphere measured along the vertical line indicated as the *parieto-temporal depth;* the distance from the mesial border of the hemisphere to the fissure we shall term the *parietal depth;* and the measurement from the

fissure to the inferior border of the hemisphere we shall speak of as the *temporal depth.*

The entire breadth of the hemisphere, or, in other words, the parieto-temporal depth, was reckoned as being equal to one hundred, and indices were then calculated which represented the relative parietal depth, the relative temporal depth, and also the relative position of the Sylvian fissure with reference to the squamous suture.

XIII. **Relative position of the Sylvian Fissure with reference to the Squamo-parietal Suture.**—We shall examine this aspect of the question in the first instance. In the adult the position of the fissure with reference to the suture was determined in seventeen cases, and the following Table gives the results which ensued:—

Relative position of the Sylvian Fissure with reference to the Squamous Suture in the Adult.

Temporo-parietal depth = 100.

—	—	17 Hemispheres.	Male. 10 Hemispheres.	Female. 7 Hemispheres.	Right. 8 Hemispheres.	Left. 9 Hemispheres.
Fissure immediately subjacent to the fore-part of the suture, . .	No. of times noted, . .	5	2	3	2	3
Fissure at a higher level throughout than the suture, . . .	No. of times noted, . .	6	5	1	4	2
	Average Index	3·6	3·3	3·6	3·8	2·5
Fissure at a lower level than the fore part of the suture, . .	No. of times noted, . .	6	3	3	2	4
	Average Index	4·1	3·3	4·1	5·7	3·2

Six of the heads from which these measurements were taken are figured in Plates VII. and VIII., and they present each of the three conditions. In

figs. 13 and 14, the fissure is immediately subjacent to the fore-part of the suture; in figs. 12 and 16 it is above the suture; whilst in figs. 15 and 17 it is below the suture. The female head represented in fig. 15 exhibits a very extreme case of depression of the Sylvian fissure, and at the same time a very high squamous arch. The index was as high as 6·7. For many years before death this subject had been insane.

The above Table shows that the relative position of the Sylvian fissure with reference to the squamous suture is subject to considerable variation. We may conclude that it is equally common to find it above, below, or immediately subjacent to the fore-part of the suture.

I next give a Table which brings out the relation of the fissure to the suture in the fœtus, and in children. In this group I also include a youth of fifteen years old. In all of these the fissure was found above the level of the anterior part of the suture.

Relative Position of the Fissure of Sylvius with reference to the Squamous Suture in the Fœtus and Child.

Temporo-parietal Depth = 100.

Period of Growth.	Number of Hemi-spheres Examined.	Sylvio-Squamous Index.	Sylvio-Squamous Index.			
			Male.	Female.	Right.	Left.
7½ to 8 months' fœtus, ...	4	24	26·1	23·3	25·3	19·1
Full-time fœtuses (fig. 3, Pl. v.), . .	6	20·3	19·5	21·1	19·6	21·7
First year of childhood (figs. 4, 5, Pl. v.),	3	13·6	14·8	13	13·6	—
4 to 5 years (figs. 6, 7, and 8, Pl. vi.), .	5	6·5	8·7	3·3	7·1	5·8
Girl, 11 years old (fig. 9, Pl. vi.), . .	2	2·7	—	2·7	2·3	3·1
Boy, 12½ years old (fig. 10, Pl. vi.), .	1	3·4	3·4	—	3·4	—
Youth, 15 years old (fig. 11, Pl. vii.), .	2	3·6	3·6	—	2·1	5·2

The posterior limb of the Sylvian fissure is thus seen to be relatively most distant from the squamous suture at the time when it is first formed by the apposition of the lips of the upper and lower opercula of the Sylvian

region. From this period on to the end of the fifth year the fissure and the suture rapidly approach each other. After this date the process appears to go on more slowly, and as Symington has pointed out the permanent condition is in all probability gained about the eighth to the ninth year. The process, however, may be retarded or accelerated. Symington has instanced a case of retardation; whilst the head of the girl of four years old, figured in Plate VI. (fig. 6), is a remarkable example of acceleration. On the right side of this head the Sylvio-squamous index was 2·8, and on the left side 3·8. These indices would not be considered remarkable were they met with in the adult. Indeed in the head of the young man aged twenty-five years, figured in Plate VII. (fig. 12), the right Sylvio-squamous index was 4·6, and the left Sylvio-squamous index was 3·6.

To account for the great difference which is exhibited in the cranial relations of the Sylvian fissure at different periods of growth it has been supposed that, in addition to the marked changes which occur in the position of the suture, there is also a gradual depression of the Sylvian fissure itself. Further, that the depression of the fissure is brought about by a portion of the outer surface of the temporal lobe slipping round so as to take up a position on the floor of the cranium. In other words, the infero-lateral margin of the hemisphere is not fixed, but is altered so as to transfer a portion of the external surface of the hemisphere to the inferior surface. This highly ingenious theory was first propounded by Symington, and when we consider the mode of growth of the infantile cranium the hypothesis appears extremely plausible. If there is one feature more prominent than another in the infantile cranium it is the narrowness of the floor in comparison with the width of the vault. As the base gradually expands one might very naturally expect a displacement of a portion of the outer surface of the cerebrum to the under surface. At first I was inclined to accept this theory, but as the investigation advanced, I saw that it was untenable, and for this reason, that throughout all periods of growth the same sulci and the same convolutions of the temporal lobe lie between the Sylvian fissure above and the infero-lateral border of the hemisphere below. In support of this assertion I would call attention to the series of figures which are

given in Plates v., vi., vii., and viii. But my observations have not been confined to the heads that are figured. Many others have been examined with precisely the same result; and I may further state that it is not necessary for this purpose to examine the brain *in situ*, although this is, undoubtedly, the best and most accurate plan. A perfectly fresh brain transferred at once from the cranium into a saturated solution of chloride of zinc, if the removal has been carefully conducted, will, when hardened in the usual way, show distinctly the infero-lateral border. If a series of brains at different stages of growth prepared in this way be compared, the infero-lateral border will be observed to hold the same relative position in them all. We may fairly conclude therefore that it is fixed and unalterable. At the same time Symington is perfectly correct in maintaining that the Sylvian fissure, as growth advances, descends somewhat on the surface of the cerebrum. He is only at fault in the theory which he advances to account for this descent. To this aspect of the question we shall return later on.

The growth-change in the position of the squamous suture is very marked. At first the squamo-zygomatic bone is low, and does not override the lower border of the parietal, but as growth advances it extends more rapidly than the parietal bone, and ascends so as to overlap it to a considerable extent. The sutural line is always regarded as coinciding with the upper border of the squamous bone. The proportion of cranial vault above and below the highest point of the suture line in the adult is 75 : 25, whilst in the last month of fœtal life it is 81·7 : 18·3.

The growth-changes which occur in the relations of the two bones at the squamo-parietal suture are rendered clear in the four figures which are given in pp. 119–122. The lower border of the parietal bone is brought out on the exterior of each of the four skulls which are depicted by a series of holes which have been drilled along the internal sutural line. A series of measurements on these and other skulls established the following facts: 1. That the lower border of the parietal bone virtually maintains the same relative position throughout all periods of skull-growth; and 2. That the overlapping is entirely due to the upward growth of the squamosal bone. Indeed we may take it as a law that the relations which the internal sutural

lines present to the subjacent cerebrum are much more fixed than the relations of the external sutural lines.

To a large extent, then, the difference which is noted in the relative position of the Sylvian fissure with reference to the external squamous suture may be accounted for by a gradual rise of the sutural line on the outer surface of the cranium. As we shall see, however, this only accounts for the change in part.

XIV. **Relative position of the Sylvian Fissure with reference to the mesial and infero-lateral borders of the cerebral hemisphere at different periods of growth.**—Great as the growth-change which we have just indicated in connexion with the squamous sutural line is, it is nearly equalled by that in the position of the Sylvian fissure on the surface of the hemisphere. The fissure descends rapidly during infancy and early childhood, so as to increase the depth of the fronto-parietal region and diminish that of the temporal lobe. In the following Table this change is brought out. In preparing the indices which indicate the parietal depth and the temporal depth, the entire breadth of the hemisphere from the mesial to the infero-lateral border is reckoned as being equal to 100 :—

RELATIVE POSITION OF THE SYLVIAN FISSURE ON THE SURFACE OF THE CEREBRAL HEMISPHERE.

Temporo-parietal Depth = 100.

Period of Growth.	Number of hemispheres. Examined.	Parietal Depth.	Temporal Depth.	Right.		Left.	
				Parietal Depth.	Temporal Depth.	Parietal Depth.	Temporal Depth.
$7\frac{1}{2}$ to $8\frac{1}{2}$ fœtuses,	11	61	39	60·6	39·4	61·4	38·6
Full-time fœtuses,	11	61·6	38·4	61	39	62·4	37·6
First year of life,	9	63·9	36·1	64·6	35·5	62·5	37·5
4 to 5 years, . .	11	65·7	34·3	65·9	34·1	65·4	34·6
11 to 15 years, .	10	69·1	30·9	69·7	30·3	68·8	31·5
Adult, ...	68	69·1	30·9	69·7	30·3	68·5	31·5

There is, apparently, no difference in this growth-change between the male and the female, and, therefore, I have not introduced the indices which I have obtained for the two sexes into this Table. If we take the adults as an example, the average male indices were 69 and 31, whilst in the female they were 69·1 and 30·9; and a similar correspondence was found for each period of growth.

The figures in the above Table render it evident that the Sylvian fissure from the last month of fœtal life, and throughout the early years of childhood, steadily descends until the parietal depth has gained 8 per cent. of the entire breadth of the outer surface of the hemisphere, whilst the temporal depth is diminished to a corresponding extent.

Throughout the whole of this growth-change the left hemisphere lags slightly behind the right hemisphere. This is exactly the reverse of what might be expected, seeing that on the left side the Sylvian angle is more open than on the right side. It is difficult to explain this apparent discrepancy; but it must be borne in mind that the measurements were made along only one line, and that the Sylvian angle is greatly influenced by the inclination of the terminal part of the fissure.

That this relation of the fissure of Sylvius to the two borders of the hemisphere exercises a great influence in modifying its position with reference to the squamous suture, is made very manifest by calculating the parietal and temporal depth indices in special cases, and comparing the results with the Sylvio-squamous indices. Thus, in the five adults in which the fissure was immediately subjacent to the fore-part of the squamous suture the average parietal depth index was 68·9; in the six adults in which the fissure was placed above the suture the average parietal depth index was 66·6; whilst in the six cases in which the fissure was below the anterior part of the suture the average parietal depth index was 69·6. The same is to be noted when we study exceptional cases. I have already referred to the very low position of the fissure with reference to the suture in the head represented in Pl. vii., fig. 15. In this the parietal depth index was 71·3. Again, in the head of a girl of four years old, where the fissure has already very nearly gained the adult position (Pl. vi., fig. 6), the parietal depth index is 67·3, whereas the average for this period of life is 65·7.

But we have not yet attempted to explain this descent of the Sylvian fissure as growth advances. In the first stages of the covering-in of the Sylvian fossa, the temporal operculum is more energetic in its growth than the parieto-frontal operculum which grows down to meet it. Before long, however, the parieto-frontal operculum takes the more prominent share in the enclosing of the insula, and there cannot be a doubt but that it is this excess of growth-energy, carried on through infancy and early childhood, which leads to the depression of the Sylvian fissure. But the growth-energy of the fronto-parietal and the temporal opercula does not appear to be of equal intensity along their whole length. Thus, in the adult it is usual to observe in the anterior part of the fissure a certain amount of overlapping of the inferior frontal convolution by the lower bounding lip of the Sylvian fissure, whilst further back the reverse condition, as a rule, holds good. Here, in the region of the central convolutions of the outer surface of the hemisphere, the fronto-parietal operculum commonly overlaps, to a slight extent, the temporal bank of the fissure. Eberstaller* calls attention to this arrangement.

Professor D. N. Sernoff,† of Moscow, has recently published a Paper in which he describes a very ingenious instrument which he has constructed for the purpose of mapping out the fissures and convolutions of the cerebrum on the surface of the head. This is illustrated by two charts which show, as we have stated above, that there is not only a considerable variation in the position of the squamous suture, but also in the level of the Sylvian fissure in different heads.

XV. **Topography of the Sylvian Fissure in the Apes.**—Féré, in an exhaustive Paper,‡ supplies us with a large amount of information upon the position of the various cerebral fissures in the apes, with reference to the cranial sutures. Unfortunately, the method which he adopted was not

* Das Stirnhirn, p. 11.

† "Encephalometer: an apparatus which determines the precise position of the several parts of the human brain in the living body." Preliminary Report. Moscow, March, 1889.

‡ "Contribution à l'étude de la topographie Cranio-cérébrale chez quelques singes," Journ. Anat. et Phys., vol. XVIII.

calculated to bring out these relations in every detail. Following Broca, he introduced into the brain at certain points small pegs through apertures drilled in the cranial wall, and then he removed the brain. The measurements which he gives, although they are manifestly accurate, are not sufficient for us to establish, in the case of the Sylvian fissure, a satisfactory comparison with the corresponding relations in man. The value of Féré's investigation is greatly increased by the fact that he was able to study the cranio-cerebral relations in two young orangs.

In the prosecution of this part of my research, I have examined the heads of two chimpanzees, one orang, two macaques, one cynocephalus, one hamadryas, and one cebus. In all of these, with the exception of the hamadryas and one chimpanzee, I have exposed the brain according to the method described in the Introductory Chapter, and have then modelled the entire head, with the cerebrum *in situ*. In the case of the hamadryas and the second chimpanzee, I removed the parietal bone by chiselling through the cranial wall, along the sutural lines, and when this was done pins were introduced into the brain in such a manner that they mapped out on its surface the parietal field.

The models which I obtained, with one exception (a macaque), are figured in Plate viii. (figs. 18–22).

The apes which I have examined may be classed in three groups according to the relations which are exhibited by the Sylvian fissure to the cranial sutures.

Group I.—This group comprises those in which the Sylvian fissure lies above the entire extent of the squamous suture, as in the case of the newly-born human infant. The cebus exhibits this condition.

Group II.—In this group we place those in which the front part of the squamous suture, for a considerable part of its extent, lies immediately over a corresponding portion of the Sylvian fissure. The macaques, the hamadryas, and the orang furnish us with examples of this arrangement.

Group III.—This group includes the chimpanzee and the baboon. The Sylvian fissure begins at a point some distance below the squamous suture and crosses under it as it ascends obliquely to end in the lower part of the parietal lobe.

In the cebus the Sylvian fissure lies 7 mm. above the mid-point of the squamous suture. This gives a Sylvio-squamous index of 12·7. In the baboon the Sylvian fissure crosses under the squamous suture a short distance in front of its mid-point, and at this very spot it runs into the parallel fissure. The disposition of the fissure in the chimpanzee is not in every respect similar. It crosses under the suture at a point which is situated further forwards than in the baboon, so that only a very small part of the front portion of the fissure lies under cover of the squamous bone.

The disposition in the orang undoubtedly approaches most closely to that exhibited in the adult human head. Féré has already drawn attention to this, and has pointed out that the fixed relationship between the squamous suture and the Sylvian fissure appears to be attained at an earlier date in the orang than in the human child. Both of his specimens were young, whilst mine was also very far from being full grown. I estimated its age at six years. In comparing the cranio-cerebral relations in the orang and the chimpanzee we must not lose sight of the fact that in the former there is a spheno-parietal suture as in man, whilst in the chimpanzee the squamosal bone reaches forwards so as to articulate with the frontal bone and shut off the parietal from the sphenoid. The commencement of the Sylvian fissure in the orang is placed at a level slightly below that of the spheno-parietal suture, and it is only as it passes backwards that it comes to lie immediately subjacent to the fore-part of the squamous suture.

In the orang the so-called anterior limb of the Sylvian fissure was placed subjacent to the fronto-sphenoid suture; in the chimpanzee it ascended so as to cross very obliquely the line of the fronto-squamous suture.

But it is impossible to appreciate fully the relations which the fissures of the ape-cerebrum present to the sutural lines unless we determine at the same time the precise position of the various fissures on the surface of the cerebrum. We have already done this in the case of the Sylvian fissure in the human brain (*vide* p. 144), and we have constructed indices which give an approximate idea of the relative depth of the portions of brain surface which lie above and below the Sylvian fissure. It is necessary to

do the same in the case of the ape-cerebrum. The following Table gives the required data:—

Relative position of the Sylvian Fissure on the Surface of the Hemisphere in different Apes.

Parieto-temporal Depth = 100.

—	Number of Hemispheres Examined.	Parietal Depth.	Temporal Depth.
Cebus (1 *C. capucinus*, 2 *C. albifrons*), . .	6	66·9	33·1
Baboon, ...	7	66·6	33·4
Macaque, ...	5	65·4	34·6
Hamadryas, ...	2	64·8	35·2
Orang, ...	2	71	29
Chimpanzee, ...	4	71·2	28·8

The indices presented in this Table by the low apes resemble those obtained for the human child of four to five years old (65·7 – 34·3), and this being the case, we should naturally expect that the cranial relations of these apes would show some similarity to those exhibited at the same period of human growth. This is very far from being the case. Only in the cebus is the Sylvian fissure placed above the squamous suture; in the others the fore-part of the fissure is either placed at a lower level than the suture or coincides with the suture.

In the orang and the chimpanzee the parietal depth is relatively greater than in the adult human cerebrum. This is very remarkable when we consider that the orang examined was only six years old, whilst both chimpanzees were little more than three years old.

In spite of this greater relative parietal depth in the orang, we find a close resemblance between relations presented by the Sylvian fissure and the squamous suture in this ape and the corresponding relations in the adult human head. This is, no doubt, due to the fact that the squamous bone in the orang does not reach to the same relative height as in the cranium of man. It is both interesting and curious, therefore, to note that

with a differently formed cranium and a difference in the extent of the surface areas of the brain, we should find a correspondence in the cranio-cerebral topography of the orang and of man. It would almost seem to indicate that there is some obscure relationship between the different bony factors which go to form the cranial capsule and the areas into which the surface of the cerebrum is subdivided.

It is very evident, from the facts stated above, that we cannot be too careful in instituting a comparison between the cranio-cerebral relationships of man and those of the apes; and further, that many features which, at first sight, appear to be similar in both, are found, on closer examination, to be more or less of a spurious character.

XVI. **The relation presented by the anterior limbs of the Sylvian Fissure to the Cranial Wall at different periods of growth.**—The relations of the anterior limbs of the Sylvian fissure to the cranial wall are subject, even in the adult, to a considerable amount of variation. This is due chiefly to the many different forms in which these limbs may appear, and also, but to a less degree, to a variability in the line pursued by the lower part of the coronal suture. We have noted that the two anterior limbs may be completely distinct and separate from each other. In this case, the size and degree of development of the pars triangularis of the inferior frontal convolution influences the cranial relations of both. Again, only one limb—a combination of both, and presenting very different degrees of inclination—may be present. In such cases it would be difficult to find two heads in which the anterior limb presents precisely the same cranial relations. Still further, the two limbs may be arranged in the form of a Y. In these cases the cranial relations alter with the lengthening out, or shortening of, the common stem, and also with the different degrees of divergence of the two limbs.

Such being the case, it is difficult to pick out those differences in the cranial relations of the anterior limbs of the Sylvian fissure which are due to general growth-changes. That such do exist there cannot be a doubt, and to establish this point I shall have to give in detail the observations which I have made on the cranial topography of the fissures in question.

Adults.

Let us first deal with the adults. Of these I have studied six, the heads of which, with the brain exposed *in situ*, were all modelled. Five of the models in question are figured in Plates VII. and VIII. (figs. 12, 13, 15, 16, 17); but the models were not well adapted for this part of the inquiry. The bars of bone which were left in the lines of the sutures concealed too much of the area and often hid the anterior limbs completely or in part. My observations have therefore been made directly on the specimens after the moulds were prepared and after the removal of portions of the bony bars. In some cases it was necessary to remove the cerebrum after fixing the lines of the sutures by means of pins introduced into the brain.

In dealing with the heads of adults it is often difficult to establish the precise coronal line in its lower part, because it is here that obliteration of the suture is so apt to occur. This is all the more unfortunate, seeing that it is in this part of the suture that the overlapping squamous process of the parietal bone leads to changes in the direction of the coronal line as growth goes on (figs. 28–31, pp. 119–122).

1. *Elderly male* (not figured).—Both ascending and horizontal limbs present, and both on the outer face of the hemisphere. The coronal suture crosses the base of the ascending limb, whilst the horizontal limb skirts the spheno-frontal suture.

2. *Young male, twenty-five years old* (fig. 12).—Both ascending and horizontal limbs present on the outer surface of the hemisphere, but both short. In the figure they are concealed by the bars of bone. The ascending limb is placed along its whole length immediately behind the coronal suture; the horizontal limb lies immediately above the fore-part of the spheno-parietal and the back part of the spheno-frontal sutural line.

3. *Elderly male, seventy-five years old* (fig. 16).—In this head a portion of the insula is exposed through the non-development of the pars triangularis. The exposed part of the insula is placed immediately behind the coronal suture—the lip of the orbital operculum very nearly coinciding with the coronal line.

4. *Male* (*centenarian*) (fig. 17).—Single anterior limb. In the figure this is hidden by the sutural bars of bone. It begins at the postero-superior corner of the great wing of the sphenoid and extends upwards and forwards behind the coronal suture. Its extremity intersects the coronal line, but can hardly be said to extend in front of it.

5. *Elderly female* (fig. 15).—In this head the spheno-parietal suture is extremely short. Both ascending and horizontal limbs are present on the outer surface of the hemisphere. The base of the ascending limb is 6 mm. behind the coronal suture. From this it extends upwards and forwards, and is crossed at the junction of its upper and middle thirds by the coronal suture. The horizontal limb runs along the upper border of the great wing of the sphenoid, and is crossed near its commencement by the coronal suture.

6. *Female, thirty-five years old* (fig. 13).—Both the ascending and the horizontal limbs are present on the outer surface of the hemisphere, but both are covered in the figure by the bars of bone. The ascending limb is for the most part placed behind the coronal suture, but it is crossed by the sutural line near its extremity. Its base corresponds with the postero-superior angle of the great wing of the sphenoid. The horizontal limb runs along the upper margin of the great wing of the sphenoid.

Children from Eleven to Fifteen years old.

The three heads of this period in which I have studied the cranial topography of the anterior limbs of the fissure of Sylvius are figured in Plates VI. and VII. (figs. 9, 10, and 11).

1. *Youth, fifteen years old* (fig. 11).—In this head the horizontal limb is completely on the orbital surface of the hemisphere. The ascending limb in the figure is covered by the coronal bar of bone. In its lower two-thirds it lies immediately behind the coronal line; while its upper third is placed immediately in front of the suture.

2. *Boy, twelve and a-half years old* (fig. 10).—Single anterior limb alone present. Its base is placed behind the coronal line, but as it extends forwards and upwards it intersects the sutural line, so that two-thirds of

its length lies in front of the suture. This portion of the fissure is seen in the figure.

3. *Girl, eleven years old* (fig. 9).—Both ascending and horizontal limbs present on the outer face of the hemisphere. The ascending limb is short, and is concealed in the figure by the coronal bar of bone. Its base lies immediately behind the suture, whilst the remainder of the fissure is placed immediately subjacent to the coronal line. The horizontal limb lies higher than in any of the preceding heads. It arises immediately behind the coronal suture, and then proceeds forwards under cover of it to end, a short distance above the line of the spheno-frontal suture. The termination of this fissure is seen in the figure.

Children from four to five years old.

Three children of this period have been studied with the view of determining the topography of the anterior limbs of the Sylvian fissure. The heads of these are figured in Plate vi. (figs. 6, 7, and 8).

1. *Boy, four years old* (fig. 7).—Single anterior limb alone present. This is placed very far back; indeed its base is 10 mm. behind the coronal suture. From this it ascends upwards and forwards, and its extremity lies subjacent to the coronal suture close to the stephanion.

2. *Girl, four years old* (fig. 6).—The two anterior limbs present the Y-shaped condition, and are seen in the figure. The stem of the Y, with the ascending limb, extend, very nearly perpendicularly upwards, and is placed 8 mm. behind the coronal line. The horizontal limb of the Y stretches horizontally forwards, and crosses subjacent to the coronal line immediately below the stephanion, and 19 mm. above the level of the upper border of the great wing of the sphenoid.

3. *Boy, five years old* (fig. 8).—In this head the horizontal limb is on the orbital face of the hemisphere. The ascending limb, with the exception of the base which lies behind the coronal suture, is covered by the coronal bar of bone. It is crossed a little above its middle point, and at the level of the stephanion by the coronal line.

Infants in the first year of life.

Four heads of children in the first year of life have been examined with the view of ascertaining the position of the anterior limbs of the Sylvian fissure in relation to the cranial wall. Two of these are figured in Plate v. (figs. 4 and 5).

1. *Female child, one year old* (fig. 4).—Both ascending and horizontal limbs on the outer face of the hemisphere. The ascending limb is crossed at its base by the coronal line. Its upper two-thirds lie in front of the coronal suture. The horizontal limb is very short, and is covered by the coronal bar of bone. It lies high above the level of the great wing of the sphenoid.

2. *Female child, six months old* (fig. 5).—The horizontal limb is placed on the orbital surface of the frontal lobe. The ascending limb at its base is 5 mm. behind the coronal line. From this it extends upwards and forwards, and is crossed by the coronal line at the junction of its upper and middle thirds. The point at which it is crossed by the coronal line is 16 mm. above the level of the pterion.

3. *Male child, six months old.*—The two anterior limbs are arranged in the form of a Y. The stem of the Y is immediately subjacent to the coronal suture, whilst both limbs are in front of it.

4. *Female child, three months old.*—The two anterior limbs are arranged in the form of a Y. The stem of the Y and the ascending limb are immediately subjacent to the coronal line, whilst the horizontal limb stretches forward in front of it at a considerable height above the upper border of the great wing of the sphenoid.

Full-time fœtuses.

Of these I have examined four, of which one is figured in Plate v. (fig. 3). Owing to the fact that at this stage the Sylvian fossa is not completely closed in, the position of the anterior limbs of the Sylvian fissure cannot be determined with the same precision as in the later periods of life.

In one male fœtus (fig. 3) there was only one anterior limb. This was crossed at its base by the coronal line, whilst the remainder of it was placed in front of the suture. In the figure this fissure seems to possess the Y-shaped arrangement, but this is not the case, as the upper of the two branches is merely a secondary sulcus.

In all the other full-time fœtuses examined, both of the anterior limbs were placed completely in front of the coronal line.

In the adult head the variations in the position of the anterior limbs of the Sylvian fissure with reference to the cranial wall are confined within certain definite limits, and seem to depend upon: (1) the length of the spheno-parietal suture; (2) the extent of the overlapping squamous portion of the lower part of the anterior border of the parietal bone; (3) the extent of the overlapping portion of the squamous upper margin of the great wing of the sphenoid; (4) the degree of development of the pars triangularis of the inferior frontal convolution; and (5) the level at which the Sylvian fissure is placed on the surface of the hemisphere. Putting individual peculiarities aside we may state in general terms that in the adult the anterior horizontal limb coincides with the upper border of the great wing of the sphenoid bone, and that the ascending limb takes origin at the postero-superior corner of the same bone, and extends upwards and forwards behind the external coronal line, so that its extremity reaches or perhaps may be crossed by the external suture.

In the youth of fifteen years old, and in the girl of eleven years old, the conditions observed do not deviate very much from those that we have indicated as being typical in the adult. In the boy of twelve years old, however, the single anterior limb is relatively further in advance in relation to the external coronal line. This is no doubt due in the first place to the fact that only one limb is present, and in the second place to a slight degree of development of the squamous bone overlapping part of the parietal bone.

In the children of four and five years the high position of the Sylvian fissure on the surface of the cerebrum and the low squamous bone and great wing of the sphenoid bring about a condition very different from that present in the adult. The two anterior limbs are placed high above the level of the spheno-parietal and spheno-frontal sutural line, and even come

into relation with the stephanion. In the growth of the cranium the upper edge of the great wing of the sphenoid ascends over the lower border of the parietal bone in the form of an extensive squamous process (figs. 28–31., pp. 119–122).

Further, as the base of the cranium expands, the vertical portion of the ali-sphenoid becomes more upright. As the result of these changes the external sutural line corresponding to the upper margin of the great wing of the sphenoid assumes a higher position on the side of the cranial wall, and comes into relation with the anterior limbs of the Sylvian fissure on the surface of the cerebrum.

The two children of four years old present one feature in common which is very hard to explain. The anterior limbs of the Sylvian fissure are placed far behind the coronal suture. This must be an individual peculiarity: certainly it cannot be a growth-change peculiar to this period.

In the first year of life, and in the full-time fœtus, the high relative position of the anterior limbs becomes still more apparent. Further, the position of the coronal line in its relation to these limbs is very different from that exhibited in older specimens. Thus we have noticed that in the full-time fœtus both the anterior limbs of the Sylvian fissure, as a rule, lie in front of the line of the coronal suture. This was to be expected from what we have already observed in connexion with the topography of the island of Reil (p. 119). In the early stages of growth the lower end of the coronal suture moves forward so as to take up later on a more advanced position on the side of the skull. As it does so it gradually acquires a new position with reference to the ascending limbs of the Sylvian fissure.

Féré noticed this change in the relative positions of the coronal suture and the anterior limbs of the Sylvian fissure. He says: "Chez l'adulte, dans les deux sexes, le ptérion répond à l'intervalle compris entre les deux branches moyennes de l'M formé par la troisième circonvolution frontale . . . . chez les jeunes enfants, le ptérion, considéré dans ses rapports avec la circonvolution, m'a toujours paru situé sur un plan plus postérieur que chez l'adulte; il correspond, non pas à l'anse médiane de l'M de

troisième frontale, non pas au cap de Broca, mais à la queue de cette circonvolution, à la partie postérieure, à celle qui est plus specialement affectée au langage." *

XVII. **Summary.**—1. As growth proceeds the outline of the Sylvian fossa changes considerably. The diagram on page 79 illustrates this. At first, nearly circular, it elongates in a vertical direction and then bends backwards on itself and assumes a triangular outline.

2. The high prominent mantle-border or rim which surrounds the depression is divided by intervening angles into four sections, viz. the *temporal*, or lower; the *fronto-parietal*, or upper; the *frontal*, which is formed by an opening out and flattening of the primitive single anterior angle; and an *orbital*, or front portion.

3. Each of these portions of the bounding rim acts as an independent line of growth, and consequently, in course of time, four opercula grow over the Sylvian area so as to enclose it. The temporal and fronto-parietal opercula appear first; the frontal and the orbital do not develop until a much later period.

4. The so-called three limbs of the fissure of Sylvius are formed by the meeting over the Sylvian area of the contiguous lips of the four opercula. The posterior horizontal limb intervenes between the fronto-parietal and the temporal opercula; the anterior ascending limb between the frontal and fronto-parietal opercula; and the anterior horizontal limb between the frontal and the orbital opercula.

5. The frontal operculum is therefore the same as the "cap de Broca," and it shows great variations in its growth. It may be absent altogether and then the two anterior limbs of the Sylvian fissure are fused into one. When the frontal operculum is reduced in length we have the Y condition of the two anterior Sylvian rami.

6. The Sylvian fossa once mapped out on the surface of the hemisphere extends very rapidly. This growth is not proportionate with that of the hemisphere; it is much more rapid.

* Revue d'Anthropologie, 1879.

7. During intra-uterine life the anterior end of the insula maintains a very nearly fixed position with reference to the anterior end of the cerebrum, whilst the posterior end moves rapidly towards the occipital pole. After birth the posterior end of the insula is fixed, whilst the anterior end, as growth advances, oscillates slightly—at first approaching and then retreating from the anterior end of the cerebrum.

8. An anterior limb of the Sylvian fissure can only be determined by the following tests: (*a*) It must cut right through the entire thickness of the operculum and reach the furrow surrounding the island of Reil; (*b*) It must be a primitive deficiency in the opercular covering of the insula; (*c*) It must lie in front of the inferior præcentral sulcus.

9. A single anterior limb of the Sylvian fissure was present in 30 per cent. of the hemispheres examined; the two anterior limbs quite distinct and separate were present in 37·5 per cent.; the Y-shaped condition of the two limbs was present in 32·5 per cent.

10. The two orbital limbs of the Sylvian fissure cannot be regarded as belonging to the same category as the true anterior limbs. They are not developed as primitive deficiencies in the orbital operculum.

11. The posterior insula is not connected with the extremity of the temporal lobe, as Eberstaller has asserted, but with the limbic lobe.

12. On the surface of the fœtal insula there appear three radial furrows which correspond in every respect with the three radial "Primärfurchen" on the outer surface of the mantle (viz. the fissure of Rolando, the inferior præcentral sulcus, and the vertical limb of the intra-parietal sulcus). The radial furrows on the insula clearly belong to the same fissural system and intermediate links between the three radial fissures on the outer surface of the hemisphere, and the three radial fissures on the insula may exist in the form of secondary sulci cutting the margin of the fronto-parietal operculum.

13. The fissure of Rolando is clearly the proper boundary of the frontal lobe. Above, it is only separated from the calloso-marginal fissure which bounds the lobe internally by a narrow, but superficial gyrus; below, the inferior transverse furrow of Eberstaller acts as an intermediate link between it and the sulcus centralis insulæ. The sulcus centralis insulæ and the calloso-marginal sulcus are brought into close relationship at the

anterior perforated spot on the base of the brain. An almost continuous fissural system, therefore, marks out the limits of the frontal portion of the cerebrum.

14. The temporal pole is formed entirely by the forward growth of the fore-part of the temporal operculum.

15. In the adult brain the insula is relatively longer in the male than in the female. At all periods of growth it would seem that the insula is relatively longer on the left side than on the right side. In the negro brain it would appear that the insula is relatively shorter than in the European brain.

16. In the anthropoid ape the so-called anterior limb of the Sylvian fissure is not homologous with either of the anterior limbs in man.

17. In the chimpanzee and orang there are only two opercula, viz. the fronto-parietal and the temporal. The frontal and the orbital opercula of the human brain are entirely absent in the anthropoid cerebrum.

18. Restricting the term insula to that part of the hemisphere surface which is concealed from view by opercula, the extent of this area in the ape is very much less than in man. The central index is 18·2 in the chimpanzee and 21·5 in the orang; in man the central index is 29·6. In the lower apes the central index is higher than in the anthropoids.

19. In man the field of the insula shows marked changes with reference to the cranial wall during intra-uterine life. More and more of its area come to lie under cover of the parietal bone, and relatively less under cover of the frontal bone, as development proceeds. In the adult the coronal line cuts the insula in such a manner that 13 per cent. of its length lies in front of it, and 87 per cent. behind it.

20. In the chimpanzee and the low apes no part of the insula lies in front of the coronal line; in the orang the upper and anterior corner of the insula projects slightly in front of this line.

21. In the human infant and young child, as well as in the ape, the point at which the stem of the Sylvian fissure reaches the outer surface of the hemisphere is situated relatively further back than in the human adult.

22. The Sylvian fissure is relatively longer in the left hemisphere than in the right, and in the ape than in man.

23. The angle of the Sylvian fissure is more acute in the human infant and child, and also in the ape, than in the human adult; it is also, in man, more acute in the right hemisphere than in the left. It is apparently little influenced by the form of the head.

24. At the time when the posterior limb of the Sylvian fissure is first formed by the apposition of the lips of the upper and lower opercula of the Sylvian region, it is placed far above the squamous suture. The relative distance between the fissure and suture is greater at this period than at any other stage of growth.

25. From this period to the end of the fifth year the fissure and suture rapidly approach each other; but after this date the process goes on more slowly, and the permanent condition is gained about the ninth year. Very frequently the process is retarded or accelerated.

26. This change in relative position is brought about—(*a*) by a rise of the sutural line, or in other words, of the upper margin of the squamous bone; (*b*) by a descent of the posterior limb of the Sylvian fissure on the outer surface of the hemisphere.

27. The descent of the Sylvian fissure on the outer surface of the hemisphere is not produced by a portion of the outer surface slipping round so as to take up a position upon the broadening floor of the young cranium, but by a growth antagonism between the fronto-parietal and temporal opercula, in which the former gains the victory by pushing down the latter.

28. In cebus the Sylvian fissure lies above the level of the squamous suture; in the macaque, hamadryas, and orang, it lies immediately subjacent to the fore-part of the suture; in *Cynocephalus anubis* and the chimpanzee the fissure is situated in its fore-part below the level of the front part of the suture.

29. The relative depth of the parietal and temporal lobes in the lower apes resembles that in the human child; in the anthropoid ape the relative parietal depth of the hemisphere exceeds that in the human adult.

30. The topography of the two anterior limbs of the fissure of Sylvius is subject to a considerable amount of variability.

CHAPTER III.

THE FISSURE OF ROLANDO.

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I. **Historical Notice.**—The name of "Rolando" was first applied to this fissure by Leuret* in 1839, and it has very generally been accepted in France, Italy, and England. At the same time it must be admitted that Rolando † added little to what was at that time already known of the fissure. He describes the two convolutions between which it lies, and likewise figures it; but many years prior to this it had been figured both by Vicq d'Azyr ‡ and by Gall and Spurzheim.§ Not only this, but Rolando freely acknowledges the priority of Vicq d'Azyr in the matter. Broca,‖ in an extremely interesting article, explains how it came about that Leuret passed over the claims of his own countryman. It would appear that Leuret possessed an edition of the works of Vicq d'Azyr which was represented as being complete, and yet which had been mutilated and falsified

* Anatomie comparée du système nerveux. Paris, 1839.

† "Della struttura degli hemispheri cerebrali." In Memorie del reale Accademia della Scienze di Torino, t. xxv., p. 163, 1831.

‡ Traité d' anatomie et de physiologie. Paris, 1796.

§ Anatomie et physiologie du système nerveux en général et du cerveau en particulier. Paris, 1810.

‖ Note sur la topographie cérébrale et sur quelques points de l'histoire des circonvolutions, Bulletin de la Academie de Médecine, 8 Août, 1876, p. 824.

by an unscrupulous editor.* Through this accidental circumstance the name of "Rolando" has become associated with the fissure.

German observers, with the single exception of Pansch, apply to the sulcus the term "*Centralfurche*," a name which was introduced by Huschka† If this term be applied to it with the view of indicating its nearly central position with reference to the frontal and occipital poles of the hemisphere it must be admitted that it is singularly appropriate. But it was not with this signification that it was used by Huschka. Following the views which had been advanced by Leuret, he imagined that the fissure of Rolando passed through the midst of the arching convolutions of the carnivore brain, and separated them into an anterior and a posterior set. The term fissura centralis was founded upon this erroneous conception of its homology, and it was owing to this that Pansch‡ so strenuously and properly objected to its use.

II. **General Description.**—The most complete and at the same time the most accurate description of the fissure of Rolando in the adult with which I am acquainted is that which has recently been given by Dr. Oscar Eberstaller of Graz.§

It is customary to describe the upper end of the fissure of Rolando as falling short of the upper margin of the cerebral hemisphere; but, as Eberstaller has pointed out, this is not correct. In fifty-two hemispheres, taken from children and adults, I found the following:—

(*a*) In 60 per cent. the upper end of the fissure cut the upper border of the hemisphere, and appeared on the inner surface.

(*b*) In 21 per cent. it just reached the upper border, but did not show upon the inner surface.

(*c*) In 19 per cent. it fell short of the upper border.

* Published in 1805 by Moreau (of Sarthe).

† Schädel, Hirn und Seele, p. 134, Jena, 1854.

‡ Die Furchen und Wülste am Grosshirn des Menschen, Berlin, 1879: also, "Bemerkungen über die Faltungen des Grosshirns, &c.," Archiv f. Psychiatrie, Band viii., p. 244, Berlin, 1878.

§ Das Stirnhirn. Wien und Leipzig, 1890.

In those cases in which the upper extremity of the fissure does not reach the superior margin of the cerebral hemisphere, as well as in those cases in which it fairly turns over to reach the inner surface, the sulcus usually ends by bending directly backwards for a distance of about a quarter of an inch or more. On the inner surface of the hemisphere it approaches the upwardly directed end of the calloso-marginal sulcus, but I have never seen it join the latter. Benedikt * describes such a union. He says : "In several brains the fissure of Rolando, which in these cases projects far upon the mesial surface, also stands in connexion with the fissura calloso-marginalis." Eberstaller doubts the existence of this connexion. In the large number of brains which he has examined, he has never met with an example.

Where the upper extremity of the fissure of Rolando just reaches the upper border of the hemisphere, but fails to turn round it, we do not as a rule see the terminal backward bend which is so characteristic of the two other forms of ending.

Eberstaller believes that the upper end of the fissure of Rolando almost invariably turns over the upper border of the hemisphere. He says:— "Die Centralspalte überschreitet fast immer die Mantelkante, und endet erst auf der Innenfläche der Hemisphäre; zum mindesten wird die Mantelkante erreicht, und ist somit das Furchenende bei der Betrachtung der Medianfläche wahrnehmbar; dass die Mantelkante nicht erreicht wird, ist eine seltene Ausnahme."

In the great majority of cases the lower end of the Rolandic fissure falls short of the fissure of Sylvius. In 19 per cent. of the same fifty-two hemispheres to which I have already referred, and which comprised a nearly equal number of male and female brains, a shallow connexion was established. The cases in which this was observed may be classified as follows:—

6 times on the right side.	4 times in the female.
4 times on the left side.	6 times in the adult.
6 times in the male.	4 times in children.

I may further state that although I examined twenty-one hemispheres of the new-born child, the connexion was only present in one instance.

* Anatomische Studien an Verbrecher-Gehirnen. Wien, 1878.

These results are very different from those which have been obtained by either Benedikt or Giacomini. The first of these authorities, in thirty-eight hemispheres found a complete connexion between the Rolandic fissure and the Sylvian fissure in eighteen cases, and an incomplete connexion in other six.* Giacomini,† on the other hand, examined 336 hemispheres, and in only 21 of these was the communication present.

Eberstaller gives us what appears to me to be the true explanation of this occasional communication between the fissure of Rolando and the fissure of Sylvius. He points out that in most hemispheres a small variable tertiary furrow may be detected upon the margin of the fronto-parietal operculum below the lower end of the Rolandic fissure. To this he gives the name of the inferior transverse furrow of the fissure of Rolando. It takes an oblique course upwards and forwards, and is usually separated from the under end of the fissure of Rolando by a superficial gyrus which connects the two central convolutions. Sometimes, however, the fissure of Rolando opens into the inferior transverse furrow, and in such cases the latter may appear as a transverse termination to the main furrow; or should the inferior transverse furrow be in connexion with the Sylvian fissure, which it most frequently is, a direct but superficial communication between the Rolandic and Sylvian fissures is established. In either case, if the lips of the fissure of Rolando in its lower part be separated from each other, the superficial gyrus which intervenes between the two sulci under ordinary circumstances will be observed pressed down into the bottom. This marks the lower limit of the normal fissure of Rolando. Its shallow onward prolongation into the Sylvian fissure, or the transverse terminal branch, as the case may be, is in reality an additional element—the inferior transverse sulcus of Eberstaller. These facts I can verify in every particular.

The connexion between the fissure of Rolando and the inferior transverse sulcus is of late occurrence. In only one full-time fœtal hemisphere have I noticed it, and even here the annectant gyrus was barely

* Anatomische Studien an Verbrecher-Gehirnen, p. 96. Wien, 1872.

† Varietà delle circonvoluzioni cerebrali dell' uomo. Torino, 1882.

concealed within the fissure. On the other hand, at no time can one study more satisfactorily the inferior transverse sulcus than in the two last months of intra-uterine development. It is almost invariably present, and it is almost always seen turning round the lower border of the operculum below the lower end of the fissure of Rolando (Pl. i., fig. 33, *i. t.*; Pl. ii., fig. 24; Pl. iv., fig. 1, *i. t.*).

I believe that where the union between the fissure of Rolando and the inferior transverse sulcus takes place, it usually leads to a direct connexion between the former and the fissure of Sylvius. In only four cases have I seen the deep annectant gyrus crossing the bottom of the lower end of the fissure of Rolando without such a connexion being established.

In the chimpanzee the deep annectant gyrus in the lower part of the fissure of Rolando, which indicates a union with the inferior transverse furrow, appears to be usually present. In only one out of four hemispheres in my possession is it absent. In the other three it is strongly marked, and in one of these there is a superficial connexion between the fissure of Rolando and the fissure of Sylvius. Even in that hemisphere, in which there is no trace of the deep annectant gyrus, it appears likely that a fusion between the fissure of Rolando and the inferior transverse furrow has taken place, because the sulcus is not any shorter and it reaches as low down as in the case of the other hemispheres. The union, however, is of a more complete kind.

In the orang, also, I find in two hemispheres a very distinct deep annectant gyrus crossing the bottom of the inferior part of the fissure of Rolando, and partially cutting off a small portion which probably represents Eberstaller's inferior transverse furrow. When I deal with the development of the fissure of Rolando I shall again have occasion to allude to this deep annectant gyrus, and to point out its importance from a morphological point of view.

But the inferior transverse furrow of Eberstaller is not confined to the chimpanzee and the orang. It is also present in a well-marked form in the baboon and the macaque; and in both of these forms it is often split up into two distinct parts—an upper and a lower (fig. 33). This gives us a key to a condition which is by no means uncommon in the

chimpanzee and orang. I refer to the presence of a deep annectant gyrus in the lower part of the fissure of Rolando, indicating, no doubt, the junction of the latter with an additional lower element, and also of a short, oblique, and independent furrow below and in front of the lower extremity of the fissure of Rolando, and in relation to the margin of the fronto-parietal operculum.

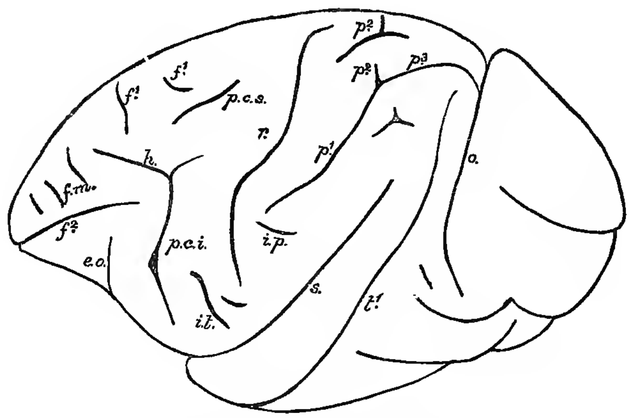

FIG. 33.—Lateral view of the left hemisphere of a Chacma baboon, the mesial border of the hemisphere having been raised considerably. Drawn by the American apparatus* for tracing orthogonal projections of the skull.

r. . . .	Fissure of Rolando.	*f. m.* .	Sulcus frontalis medius (?)
i. t. . . .	Two inferior transverse furrows of the fissure of Rolando.	*f.*^{2} . .	Sulcus frontalis inferior.
p. c. s. . .	Sulcus præcentralis superior, with basal part of the superior frontal sulcus.	*e. o.* . .	Sulcus fronto-orbitalis.
		s. . . .	Sylvian fissure
p. c. i. . .	Sulcus præcentralis inferior.	*p.*^{1} . .	Sulcus postcentralis inferior.
h. . . .	Ramus horizontalis of sulcus præcentralis inferior.	*p.*^{2} . .	Sulcus postcentralis superior.
		p.^{3} . .	Ramus horizontalis parietalis.
		t.^{1} . .	Parallel sulcus.
f.^{1} . .	Sulcus frontalis superior.	*o.* . . .	Anterior lip of the occipital operculum.

Between its two extremities the fissure of Rolando pursues a sinuous course. Very seldom in the adult brain is it quite straight. As Eberstaller and others have shown, two of the bends, termed respectively the superior and inferior genua, are more conspicuous than the others. In typical cases these are placed at an equal distance from each other and from the two

* For a description and drawing of this most useful apparatus, see the article by Dr. W. Matthews, in the *Journal of Anatomy*, xxi., p. 43.

ends of the sulcus, so that they mark it out into three equal parts. The superior genu is usually much the weaker of the two and is directed backwards. The upper third of the fissure inclines downwards and slightly backwards. At the superior genu the sulcus bends suddenly in a forward and downward direction. The inferior genu is always strongly marked and looks forwards. Here the fissure again changes its direction and proceeds very nearly vertically downwards.

In almost every case the educated eye is able to detect these genua. Perhaps the most common deviation from the condition which we have described as being typical is one in which the central piece of the fissure of Rolando becomes considerably shortened and nearly horizontal in its direction. The two genua are thus more closely approximated, and the inferior may lie almost directly in front of the superior.

We have seen that when the lips of the fissure of Rolando are drawn widely asunder, a deep annectant gyrus is sometimes seen in its lower part. But this is not the only one which may be present. In the neighbourhood of the superior genu there is generally a shallowing of the fissure and a deep interlocking of its adjacent walls. Two of the interdigitating gyri—one projecting backwards from the anterior central convolution and the other forwards from the posterior central convolution—are always larger and more pronounced than the others, and in a considerable number of cases they unite at the bottom of the sulcus in the form of a distinct deep gyrus, which constitutes a marked interruption in its floor. All gradations between a mere shallowing with an interlocking of the adjacent walls of the fissure and the presence of a distinct deep annectant gyrus are met with. This is a point of considerable morphological importance, as we shall see later on, and it is one to which Eberstaller has specially referred.

The following points I have specially noticed in regard to this bridging gyrus in the human brain: (1) it is not more strongly marked in the brain of a full-time fœtus nor in the brain of a child than in the adult; (2) it varies slightly in its position; it may be higher or lower, but it is usually placed in relation to the superior genu of the fissure and opposite the first frontal gyrus; (3) the more usual condition exhibits no direct

union in the bottom of the sulcus of the opposing elevations on the opposite walls of the fissure, but always a distinct shallowing of the sulcus at this level.

In five negro brains in my possession I find the deep annectant gyrus at the level of the superior genu present in each hemisphere. Not only is the condition more distinctly marked than in the European, but in one

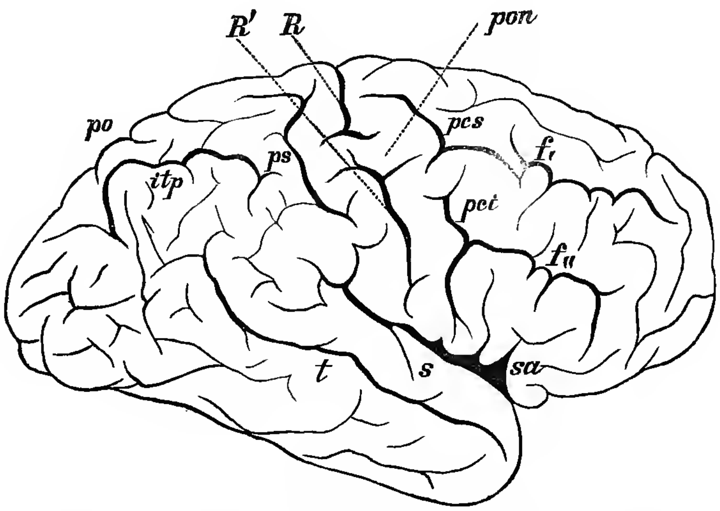

FIG. 34.—Sernoff's figure of a completely interrupted fissure of Rolando. Reproduced by the kind permission of the author. There is no history attached to the brain. It was obtained from the hospital amongst a number of others, and its only peculiarity was the interrupted fissure of Rolando.

R'.	Lower piece of the fissure of Rolando.	*p. s.*	Sulcus postcentralis.
R.	Upper piece of the fissure of Rolando.	*i. t. p.*	Ramus horizontalis intraparietalis.
pon.	Interrupting gyrus.	*p. o.*	Parieto-occipital fissure.
p. c. s.	Sulcus præcentralis superior.	*s.*	Fissure of Sylvius.
p. c. i.	Sulcus præcentralis inferior.	*s. a.*	Anterior limb of Sylvian fissure.
*f.*¹	Sulcus frontalis superior.	*t.*	Parallel sulcus.
*f.*²	Sulcus frontalis inferior.		

hemisphere, taken from a young Timanee negress, the bridging gyrus is so strongly developed that it all but reaches the surface.

In the chimpanzee this deep annectant gyrus appears to be commonly present. The four hemispheres which I possess show it in a pronounced form in each case. The orang brain likewise gives evidence of the same

condition, but not so distinctly. There is a slight shallowing of the fissure and an interlocking of the adjacent walls, but no distinct bridging gyrus.

In rare cases in the human brain the deep annectant gyrus in question rises completely to the surface and cuts the fissure of Rolando into two separate parts. I have never seen such a condition, although a very close approach to it is observed in one of my negro brains. Wagner * described for the first time such an interruption of the Rolandic fissure in the brain of the celebrated Physician, Professor Fuchs. Heschl,† who examined no less than 2174 hemispheres, only found the anomaly in its complete form six times, viz. five times in the male brain, and once in the female brain. Eberstaller met with it twice in 200 brains. It is therefore a condition of extreme rarity. Sernoff ‡ figures a good example of this condition of the fissure of Rolando in a right hemisphere (fig. 34).

III. **Development.**—The results at which I have arrived regarding the development of the fissure of Rolando are based on the study of thirty-nine hemispheres which I have collected between the fifth and seventh months of development. I have also been supplied, through the kindness of Professor Victor Horsley, with photographs of the series of brain specimens in the Oxford Museum. Several of these show the fissure in its earlier stages.

The view which is generally entertained regarding the development of the Rolandic sulcus pictures it beginning as a slight furrow midway between the upper border of the hemisphere and the margin of the Sylvian fossa, and extending gradually and continuously in an upward and downward direction. That it may develop in certain cases this way I do not deny, but I have no direct evidence to show that it does so. In one somewhat advanced hemisphere—belonging to a brain approaching the seventh

* Vorstudien zu einer wissenschaftlichen Morphologie und Physiologie des menschlichen Gehirns als Seelenorgan, 2 Abh., 1862, Tab. 1, s. 14.

† "Die tiefen Windungen des menschlichen Grosshirns und die Uberbrückung der Centralfurche," Wiener Medicinischer Wochenschrift, 1877, No. 41.

‡ Rêdki slutchai vidoizmêneniya formy Rolandovoi borozdy i tsentralnykh izvilin mozga. (A rare case of change of form of the Rolandic furrow and central convolutions.) Moskow, 1887.

month—there is certainly an appearance which leads me to believe that the sulcus may have developed in the manner usually attributed to it. It is a clean-cut straight fissure, with its extremities equally distant from the superior border of the hemisphere and the Sylvian region; further, on breaking the hemisphere across in the line of the fissure, the latter is seen to present a uniform depth, and to be at no point interrupted by an elevation of the bottom.

There is some variability in the time at which the fissure of Rolando makes its appearance. The more usual time is the last week or ten days of the fifth month, but it is not uncommon to meet with hemispheres well on in the sixth month of development with no sign of the fissure.

As a general rule, the fissure of Rolando is developed in two separate and distinct portions (Pl. I. figs. 24 and 31; Pl. II. figs. 12, 14, 17, 18, 19, 20, and 21; r^1. and r^2.). The lower portion appears in the form of a shallow oblique groove which represents the lower two-thirds of the fully-formed sulcus. It always makes its appearance before the upper portion (Pl. II., figs. 10 and 11, *etc.*, r^1.). Its lower end is placed close to the coronal suture—perhaps, indeed, it may lie immediately subjacent to the suture—while the upper end lies further back, and reaches a point midway between the upper margin of the hemisphere and the Sylvian fossa. The upper portion of the fissure makes its appearance in the form of a deep pit or depression between the upper end of the lower portion and the margin of the hemisphere. An eminence separates the two portions of the fissure from each other. Soon, however, a faint furrow runs over the summit of this elevated intervening piece of the cortex, and the two primitive portions of the sulcus are partially united to each other (Pl. II., figs. 17, 19, and 20). As development goes on the more complete does the union become, and the more fully is the intervening eminence borne down into the bottom of the fissure. As a rule the confluence takes place rapidly, but in many cases the process appears to be retarded. Amongst my specimens I have several hemispheres in the early part of the seventh month, which still show a complete severance of the two constituent elements of the furrow.

But the portion of cerebral cortex which intervenes between the two parts of the fissure is never entirely obliterated. It disappears from the

surface, it is true, but it is still to be discerned, even in the adult brain, in the bottom of the fissure, in that shallowing or deep annectant gyrus which we have described at the junction of the upper and middle thirds of the sulcus. In some rare cases, as we have already stated, the two original portions of the fissure of Rolando remain quite distinct throughout life. In these the intervening bridge of cortex remains on the surface, and is not depressed by the fusion of the upper and lower divisions of the fissure.

Krause* has stated that the fissure of Rolando owes its origin to the constricting action of a vein which, crossing the surface of the hemisphere, opens above into the superior longitudinal sinus, whilst below it communicates with the vena fossæ Sylvii. This vein, he considers, fails to keep pace with the growth of the hemisphere, and consequently cuts into its surface and produces the fissure of Rolando. He says: "An beiden Enden blind geschlossen, steht dieser tiefe Sulcus (fissure of Rolando) in keinerlei Beziehung zu den übrigen Sulci (und Gyri), die er rücksichtslos durchkreuzt. Es handelt sich ganz einfach um eine Venen-Verbindung, die, im 4 monatlichen Fötus leicht injicirbar und hervorstechend entwickelt, später im Wachstum zurückbleibt. Beim Embryo von 14 cm. Länge und dem angegebenen Alter beträgt die Dicke der, noch ehe der Sulcus centralis sich einzukerben beginnt, seinen Verlauf markirenden Vene o, 5 mm., beim 6 monatlichen Fötus 1 mm. Es verläuft in dem Sulcus eine V. cerebralis superior, welche oben in den Sinus sagittalis superior einmundet, unten aber mit der V. fossæ Sylvii communicirt." I must confess that I have been able to find no confirmation of this view of the origin of the fissure of Rolando in the fœtal brains which I have examined. If the sulcus were produced by the pressure of a vein the ends of which were tied down at the fossa Sylvii below, and at the superior margin of the hemisphere above, it would be the middle portion of the sulcus which would appear first, and the furrow would elongate in an upward and downward direction from this. As we have noted, however, it is the lower portion of the furrow which is first developed, and the upper portion appears later as an independent

* Specielle und macroscopische Anatomie, Hannover, 1879, p. 813.

depression. Further, I have looked in vain for a vessel occupying *the bottom* of the fissure. At no period of growth can this be discovered. A vein presenting the connexions described by Krause can generally be seen coursing upon the anterior bounding lip of the fissure, but I have never observed this vein tightly drawn across the surface of the hemisphere, and never placed accurately between its lips.

We have noted that a deep annectant gyrus may be observed in the fissure of Rolando of the chimpanzee and orang, similar to that which we have described in man as occupying the furrow at the junction of its upper and middle thirds. We may assume, therefore, that the interrupted form of development of this sulcus holds good amongst the anthropoid apes as well as in man. With regard to the lower apes, we have no evidence one way or the other. The development of the fissures in the brain of the apes is still virtually unknown; and if we examine the bottom of the fissure of Rolando and the other primary furrows in a low ape we find a uniform depth throughout, and an absolute absence of deep annectant gyri. It is dangerous to argue from the adult condition alone, but still the appearances are such as would lead us to infer that the continuous and not the disrupted form of development of the primary fissures holds good amongst the lower apes.

In man and in the anthropoids the development of the fissure of Rolando is in every respect on a line with that of the other two radial "Primärfurchen" (viz. the præcentral and the intraparietal), the only differences being that it is unprovided with a horizontal part, and that its two vertical portions rapidly fuse with each other. In the case of the præcentral sulcus, the two vertical parts (viz. the præcentralis inferior and the præcentralis superior) as a general rule remain apart. The intervening portion of cerebral cortex remains on the surface. The two vertical portions of the intraparietal sulcus, on the other hand, usually run together, as in the case of the fissure of Rolando. In 19·1 per cent., however, of cerebral hemispheres they remain distinct; whereas the non-union of the two portions of the Rolandic sulcus, according to Heschl, occurs in only 0·3 per cent.

But in man, as we have observed, a third lower element may be added to the Rolandic fissure in the shape of the inferior transverse sulcus of

Eberstaller. In the anthropoid ape the connexion of this element with the main furrow appears to be more intimate than in man. Of course, in man it cannot be placed on the same footing as the other two elements, seeing that it appears so much later (eighth month),* and that it may establish other connexions besides that with the Rolandic sulcus.

As I shall point out further on, the fissure of Rolando is very much longer in the anthropoid apes than in man. If we represent the length of the fissure of Rolando in the human brain by the number 100, we find that in the chimpanzee it is 130, and in the orang 120. It appears to me, therefore, not improbable that this lower element, so variable and inconstant in its present connexions, may have had at one time a closer association with the fissure of Rolando in man. In all the anthropoid hemispheres in my possession, with one exception, the lower portion of the fissure of Rolando is partially cut off by a deep annectant gyrus.

It is not uncommon to find the lower portion of the præcentral fissure developed in the earlier part of the fifth month, prior to the appearance of the fissure of Rolando. I have six hemispheres which show this condition, and under these circumstances the præcentral sulcus is very apt to be mistaken for the fissure of Rolando. Its position in front of the middle of the hemisphere and in front of the coronal suture should, in all cases, enable us to detect its true nature (Pl. i., figs. 14 and 17; also Pl. ii., figs. 8 and 9, *p. c.*). At the same time, I may mention that it was not until I had obtained two hemispheres belonging to this early period, in which the fissure in question was strongly marked, and in which also there was a slight trace of the fissure of Rolando, that I was thoroughly satisfied as to its identity. I have only seen one hemisphere in which the third radial "Primärfurche" or intraparietal sulcus was developed before the Rolandic sulcus.

The inferior genu of the fissure of Rolando always makes its appearance before the superior genu. As Eberstaller has stated it is usually well-marked about the seventh month of intrauterine development. This is

* In one hemisphere, between the seventh and eighth months, I have seen it making its appearance (Pl. ii., fig. 24); but, as a rule, it does not come into existence until the eighth month.

exactly what one might expect, seeing that amongst the lower apes the inferior genu alone is, as a rule, developed. In one specimen this genu is quite distinct upon the inferior portion of the fissure before it has joined the upper portion (Pl. II., fig. 18, *r.*[1]). As a rule, however, the fissure remains straight until the union of its two elements is complete. The superior genu is developed at the point of junction, and it is not until a later period that it assumes any degree of prominence.

The upper end of the fissure of Rolando does not overstep the upper border of the hemisphere until the beginning of the last month of intra-uterine development. In the eighth month it just reaches the margin, and I have several specimens which show it in the process of turning over and in the process of developing the backward bend of its upper extremity.

From the seventh month onwards the growth of the two bounding banks of the fissure does not proceed at an equal pace. There appears to be a greater growth-energy in the posterior central convolution, and this leads in the first instance to a greater prominence of that gyrus, and ultimately to a partial overlapping of the ascending frontal convolution by the ascending parietal convolution. Heschl and Eberstaller have called attention to this. It is more obvious in the lower two-thirds of the fissure, or, in other words, opposite that portion of it which is formed by the lower element. It is owing to this that the adult fissure cuts into the cerebral surface in an oblique direction from before backwards. In certain cases this overlapping of the ascending frontal convolution by the ascending parietal may be almost imperceptible; whilst in others it is strongly marked along the whole length of the fissure.

IV. **The Topography of the Fissure of Rolando in Man.**—The points in the topography of the fissure of Rolando which I have chiefly endeavoured to arrive at are the following:—

1. The relative distance of the upper extremity (*a*) from the anterior end of the cerebrum, (*b*) from the coronal suture.
2. The relative distance of the lower extremity (*a*) from the anterior end of the cerebrum, (*b*) from the coronal suture.

To express these relations clearly, it was necessary to construct four indices, which may be respectively termed the mesial fronto-Rolandic, the mesial corono-Rolandic, the lateral fronto-Rolandic, and the lateral corono-Rolandic. In calculating the mesial indices the length of the upper margin of the hemisphere, measured by the tape from its anterior to its posterior end, is taken as the standard, and equal to 100; and in the case of the lateral indices the length of the cerebrum, measured over its lateral surface between the same points, is taken as the standard, and equal to 100.

The determination of the point which should be considered the upper limit of the fissure of Rolando on the upper border of the hemisphere was a matter of some difficulty. As already noted, the fissure usually cuts the upper border of the hemisphere, and I have always measured to the point at which it reaches this margin. But there are cases in which it falls short of the upper border of the hemisphere, and then it usually bends suddenly backwards for a short distance. In these cases I have measured to the angle of bending, and my reason for selecting that point is simply this—that, even when the fissure reaches the mesial surface of the hemisphere, as a general rule the same backward inflexion of its extremity is seen, and the angle of bending corresponds with the point where it cuts the upper border of the hemisphere.

In measuring the early fœtal brains, where in many cases the lower portion of the fissure of Rolando was alone present, the point on the mesial border of the cerebrum, from which the measurement was taken, was obtained by drawing a line upwards to the margin of the hemisphere in the direction of the furrow. In the early stages of its development (from its first appearance up to the middle of the seventh month of intrauterine life) the fissure traverses the surface of the brain in a more transverse direction than at later stages of growth. Thus we shall point out, in a later part of this chapter, that whilst in the adult the fissure of Rolando intersects the mesial plane at an angle of 71° 7, in the sixth-month fœtus the corresponding angle is 73° 6. This must be borne in mind in comparing the different indices which are given in the following Table, and which brings out the average results I have obtained in my endeavours to

localise the position of the fissure of Rolando on the surface of the cerebral hemisphere at different periods of growth:—

TOPOGRAPHY OF THE FISSURE OF ROLANDO ON THE HUMAN CEREBRUM.

Mesial Length of the Cerebrum = 100; *Lateral Length of the Cerebrum* = 100.

	Period of Growth.	Number of Hemispheres Examined.	Mesial Fronto-Rolandic Indices.	Lateral Fronto-Rolandic Indices.
Intrauterine Life.	5½ to 6½ months,	12	52·7	41·8
	6½ to 7½ months,	12	56·7	43·2
	7½ to 8½ months,	20	55·2	42·8
	Full-time fœtuses,	24	53·5	42·6
Extrauterine Life.	First year of life (comprising brains of children from 3 months to 12 months)	12	52·1	42·8
	4 to 5 years,	14	52·6	43·3
	11 to 15 years,	6	51·8	42·3
	Adults,	82	53·3	43·3

The results contained in the Table were published in the form of an abstract in the *Journal of Anatomy and Physiology* (vol. xxv.). Since then I have gone over the measurements a second time, and added materially to the number of specimens examined. As might naturally be expected, this has led to a slight alteration of the figures; but the difference is so trifling, that the general results are not disturbed.

This Table speaks for itself, so that little need be said about the various items which compose it. One point is very remarkable, and that is the stability of position which the fissure of Rolando exhibits on the surface of the cerebral hemisphere at all periods of growth.

It will be seen on glancing at the fronto-Rolandic indices that the changes which it undergoes in its position from the time that it first appears on the surface of the cerebrum up to adult life are very slight indeed. Its

lower end, as might be expected from the fact that it is first formed, shows the least change. As development and growth proceed it moves back slightly, but only to an almost inappreciable extent. When it first appears the lower fronto-Rolandic index is 41·8, but in a few weeks it soon establishes its proper relations, and from this time on it fluctuates between 42·3 and 43·3. These fluctuations can hardly be regarded as indicating differences of position at different periods of growth. If larger numbers of brains were examined, I am satisfied that they would disappear altogether.

The upper end of the fissure of Rolando is not so fixed in its relations at different periods of life. It will be seen that it is laid down very much in the same relative position that it afterwards occupies in the adult. Compare the indices 52·7 and 53·3. From this point the upper end of the fissure moves backwards until it gains an index of 56·7. This new position is apparently acquired very rapidly—in the course of about four or six weeks—and it represents the climax of the backward movement. No doubt it is produced by an accelerated growth of the upper part of the frontal lobe during the period of the change. It is curious to note in the succeeding month that a movement in the opposite direction takes place: the upper end of the fissure travels slowly forward until the index becomes 55·2 in fœtuses from 7½ to 8½ months, and finally 53·5 in the new-born full-time child. At birth, then, the upper end of the fissure becomes fixed, and remains so in after life. I do not lay any importance on the somewhat low indices obtained for the brains of the children of eleven, twelve, and fifteen years old. The number of hemispheres measured was too small to allow us to base any generalization upon the results obtained from them.

Huschka, in his remarkable work entitled *Schädel, Hirn und Seele*, published in 1854, contends that marked sexual differences can be detected in the human cerebrum. He asserts that in the male a relatively greater mass of the hemisphere lies in front of the fissure of Rolando, whilst in the female a greater mass lies behind it. To use his own words:—"Das Weib ist ein *homo parietalis* und *inter-parietalis*, der Mann ein *homo frontalis*." Rüdinger* gives expression to somewhat similar views. He insists strongly

* Ueber die Unterschiede der Grosshirnwindungen nach dem Geschlecht beim Fœtus und Neugeborenen. München, 1877.

upon the early appearance of sexual differences in the brain of the fœtus and newborn child, and specially mentions that "in the majority of male fœtal brains the frontal lobes appear more massive, broader, and higher than in the female." More recently Passet,* under the direction of Rüdinger, returns to the subject, and gives the results which he has obtained from an extended series of brain measurements. He comes to the conclusion "that the fissure of Rolando, relatively as well as absolutely, lies farther back in the male than in the female—or, in other words, that more brain matter lies in front of the fissure of Rolando in the male than in the female." Entering into further detail on this matter he remarks:—"Die Entfernung der Fissura centralis vom Vorderhirn ist beim Manne median, lateral und in der Mitte beim Manne relativ um je 4, 3, 2 mm., absolute um je 7, 4, 3 mm. grösser als beim Weibe. Es liegt also beim Manne besonders nach der Medianebene zu mehr Gehirnmasse vor der erwähnten Furche." He considers, however, that Huschka has somewhat overstated the sexual differences. Passet illustrates his views by a very ingenious diagram.

Eberstaller has gone into this question, in so far as it concerns the adult, with his usual care and thoroughness. He measured no fewer than 270 hemispheres (viz. 94 female and 176 male), and he found that the upper end of the fissure of Rolando occupies relatively the same place in the two sexes; what difference there is (0·6) is in favour of the female frontal lobe. It is to be regretted that he gives no measurements which would enable us to locate the lower end of the sulcus in the two sexes.

The results which I have obtained for the adult brain agree in every respect with those of Eberstaller,* and I would add to what he has stated—(1) that the lower end of the fissure of Rolando also holds relatively the same place on the cerebral surface in the two sexes; and (2) that at no period of growth does the fissure of Rolando exhibit in its position what we might safely regard to be sexual differences.

* "Ueber einige Unterschiede des Grosshirns nach dem Geschlecht," Archiv f. Anthrop. May, 1882.

† Das Stirnhirn. Leipzig, 1890, p. 44.

The following Table gives the relative position of the fissure of Rolando at different periods of life in the two sexes :—

Topography of the Fissure of Rolando in the Two Sexes.

Mesial Length of the Cerebrum = 100; *Lateral Length of the Cerebrum* = 100.

Age.	Number of Hemispheres Examined.	Fronto-Rolandic Indices.	
		Upper.	Lower.
Males.			
7½ to 8½ months, ...	5	54·5	44·2
Full-time fœtuses, . .	14	53·5	42·6
4 to 5 years, ...	8	52·3	43·1
Adults, ...	17	52·6	43·7
		53.2	43,4
Females.	,55		
7½ to 8½ months, ...	12	54·6	42·0 —, 5
Full-time fœtuses, . .	4	53·7	42·8
4 to 5 years, ...	6	53·8	43·8
Adults, ...	20	52·9	43·0
		53. 7	42. 9

The figures in this Table are slightly different from those given in the preceding Table, which deals with the general indices. This is due to the fact, that in the determination of the sexual question a smaller number of hemispheres were examined.

Eberstaller, as we have mentioned, has shown that in the adult, if there is any sexual difference, it is one in favour of the frontal lobe of the female. It is curious to note that the above Table shows the same in each period of growth, but the differences are extremely trifling. This is interesting in the light of what we shall afterwards note in connexion with the upper end of the fissure in the anthropoid ape. Eberstaller has pointed out that the mesial border of the left hemisphere is slightly longer than that of the right

hemisphere, but notwithstanding this the upper end of the fissure of Rolando has precisely the same relative position in both. The measurements which I have made of adult cerebral hemispheres have led me to very nearly the same results. In forty-five right hemispheres the average upper fronto-Rolandic index was 53·1; in thirty-seven left hemispheres the average index was 53·7. The difference is trifling, and therefore I believe that in the two hemispheres the upper end of the fissure of Rolando virtually holds the same relative position.

V. **Relation of the Fissure of Rolando to the Cranial Vault.**—The position of the fissure of Rolando in relation to the coronal suture at different periods of growth must next engage our attention. This is expressed in the series of upper and lower corono-Rolandic indices in the following Table:—

TOPOGRAPHY OF THE FISSURE OF ROLANDO WITH REFERENCE TO THE CORONAL SUTURE.

Mesial Length of the Hemisphere = 100 ; *Lateral Length of the Hemisphere* = 100.

	Period of Development.	Number of Hemispheres Examined.	Upper Corono-Rolandic Indices.	Lower Corono-Rolandic Indices.
Intrauterine Life.	$5\frac{1}{2}$ to $6\frac{1}{2}$ months,	5	9·9	5·6
	$6\frac{1}{2}$ to $7\frac{1}{2}$ months,	6	11·9	3·6
	$7\frac{1}{2}$ to $8\frac{1}{2}$ months,	10	17·2	9·0
	Full-time fœtus,	11	18·2	10·7
Extrauterine Life.	3 months,	5	18·6	12·8
	6 months,	3	14·4	8·6
	12 months,	2	13·6	5·1
	4 to 5 years,	12	16·5	11·3
	11 to 15 years,	3	16·1	8·8
	Adults,	15	16·7	12·9

We have seen that the position of the fissure of Rolando on the surface of the brain is subject to very slight alterations, and that in all probability

we may consider that it becomes absolutely fixed at the close of the intra-uterine period of life. Very different, however, are its relations to the coronal suture at different periods in its history. The figures obtained, it is true, are somewhat puzzling and difficult to interpret, but one point is perfectly clear, and it is this:—The parietal bone and the area of brain immediately subjacent do not grow at an equal pace. In the early stages of its development the fissure of Rolando lies close to the coronal suture, but this does not mean that it lies far forward on the brain, but simply that the parietal bone forms at a later stage a relatively greater extent of the cranial vault. The maximum amount of the frontal lobe (the district in front of the fissure of Rolando) covered by the parietal bone is reached at the third month of extra-uterine life. The upper corono-Rolandic index at this period is 18·6 and the lower 12·8. From this stage on the coronal suture in its upper parts falls back a little, and after a slight oscillation it assumes, at the fourth or the fifth year of childhood, a fixed position with reference to the fissure of Rolando. This is expressed by the index 16·5. The lower end of the suture shows changes in its position with reference to the fissure of Rolando which are less easy to understand. I cannot believe that the oscillations which are exhibited in the lower corono-Rolandic indices give expression to the usual growth changes. If we exclude from consideration all those indices which have been obtained from less than six observations, we find a steady increase in the index from the earliest periods up to adult life, viz. 3·6, 10·7, 11·3, 12·9. This, considering the fixity of the lower end of the fissure on the surface of the hemisphere, bespeaks a slow forward movement of the lower part of the suture. We know this to be the case. In the previous chapter we have had frequent occasion to refer to the circumstance which is chiefly responsible for the forward movement of the lower portion of the external coronal line. We have noted the gradual growth forwards of a squamous process from the lower part of the anterior border of the parietal bone. This overlaps the hinder border of the frontal bone, and shifts the external suture in a forward direction. The series of skulls figured in pages 119–122 illustrate this growth-change. Still anyone who examines a number of skulls must observe that the squamous process of the parietal varies greatly in extent. Sometimes fully half an inch in length, it may in other cases be found to be barely one-eighth of an

inch long. The oscillations, therefore, exhibited in the lower corono-Rolandic indices, looked at as a whole, are no doubt largely due to this.

But it may be asked: Is there any sexual difference to be observed in the position of the coronal suture with reference to the fissure of Rolando? I believe that there is, although I must at the same time admit that the number of heads examined with the view of determining this question do not justify me in speaking decisively upon the point. It would appear, however, probable, that the area of the frontal lobe covered by the parietal bone is relatively greater in the female than in the male. In the specimens which I have studied the fissure of Rolando was situated at a relatively greater distance from the coronal suture in the female than in the male. In the adult this difference was expressed by an upper corono-Rolandic index of 16, and a lower index of 12·1 for the males as against an upper index of 17·5, and a lower index of 13·9 for the females. Corresponding differences were noted at the other stages of growth studied.

Before leaving this branch of my subject it is necessary to take note of the work which has been done in the same field by Hamy, Foulhouze, Féré, Symington, and Poirier.

In an article published in 1872, Hamy makes the following extraordinary statement:*—"Chez de jeune enfants dont la ligne suturale qui vient d'être nommé différait assez peu dans son inclinaison de celle de l'adulte, nous avons constaté que le sillon de Rolando *passait en avant* de l'articulation, de telle sorte que l'os frontal, dans ses parties laterales et inférieures, se trouvait recouvrir une petite étendue du lobe pariétal." This supposed forward position of the lower end of the fissure of Rolando he seeks to associate with a feeble development in the infant of the third frontal convolution. It is all the more necessary to contradict this statement, seeing that Schwalbe appears to give some credence to it and has given it a place in his standard work on "Neurologie" (p. 575). As we have noted, the fissure of Rolando at no stage of its development lies in front of the coronal suture. In two instances I have seen the lower end just touching the sutural line, but these were cases in which it was in its earliest stage, prior to the development of its upper piece.

Foulhouze examined a large number of subjects of different ages, but

* Revue d'anthropologie, p. 428.

although he brings out many important details in connexion with the cranio-cerebral topography of the child, he only gives us absolute measurements, and consequently they have little bearing upon the present research. Féré, also, in a Paper already quoted, furnishes us with much valuable information regarding the topography of the fissure of Rolando. He refuses to believe the views put forward by Hamy, and states that in all cases the fissure of Rolando lies behind the coronal suture. He only gives absolute measurements, and he seems to regard the coronal suture as being more fixed in its position than the fissure of Rolando. Symington and Poirier* have also been led to doubt the accuracy of Hamy's statement.

VI. **Topography of the Fissure of Rolando in the Apes.**—I shall now give a Table which shows the position of the fissure of Rolando in the apes, both in relation to the cerebral surface and the cranial wall:—

Topography of the Fissure of Rolando in the Apes.

Mesial Length of the Cerebrum = 100; *Lateral Length of the Cerebrum* = 100.

	Number of Hemispheres Examined.	Upper Indices.		Lower Indices.	
		Fronto-Rolandic.	Corono-Rolandic.	Fronto-Rolandic.	Corono-Rolandic.
Chimpanzee, ...	4	55·9	16·0	39·2	7·5
Orang, ...	4	55·5	20·7	39·2	11·1
Hamadryas, ...	2	50·0	13·3	42·1	5·2
Macaque, ...	5	50·0	12·9	40·3	11·4
Cercopethecus, . . .	8	48·1	—	37·9	—
Baboon, ...	5	47·7	13·6	40·4	10·2
Cebus, ...	7	46·3	– 5·3	43·8	16·3
Mangaby, ...	8	45·4	—	41·0	—

The corono-Rolandic distance was not measured in every case, and therefore the average results which are given in this Table are not based upon so large a number of measurements as in the case of the fronto-Rolandic indices. The minus mark before the upper corono-Rolandic index of Cebus indicates in this case the relative distance *in front* of the sutural line.

* Topographie Cranio-Encéphalique, p. 24. Paris.

This Table brings out the curious fact that the upper end of the fissure of Rolando in the chimpanzee and orang is placed relatively further back than in the adult human cerebrum. In its upper part, therefore, the relative antero-posterior length of the frontal lobe in the anthropoid ape exceeds that of man; in its lower part, however, it is relatively much shorter. In the orang and the chimpanzee the lower fronto-Rolandic index is 39·2, whilst in man it is 43·3. It is a matter of some interest to observe that the permanent position of the upper end of the fissure of Rolando in the anthropoid ape (index 55·9 in the chimpanzee, and 55·5 in the orang) closely corresponds with that of the human fœtus of $7\frac{1}{2}$ to $8\frac{1}{2}$ months (index 55·2).

In the lower apes of the old world the fissure of Rolando, in its whole length, is placed relatively further forwards than in the cerebral hemisphere of man. The upper fronto-Rolandic index varies from 45·4 to 50, whilst the lower index varies from 37·9 to 42·1. In Cebus, owing to the course pursued by the fissure of Rolando the lower end of the sulcus is placed very far back, and the inferior fronto-Rolandic index is higher than in man (viz. 43·8).

As we have seen, one of the leading peculiarities of the human brain is the relatively great antero-posterior extent of the parietal lobe, and this is attained by a corresponding decrease in the length of the occipital lobe. In the anthropoid the encroachment of the parietal lobe upon the occipital territory has not proceeded to such an extent as in man, and further, in its upper part, the length of the parietal lobe is reduced by the extension backwards of the superior part of the frontal lobe. In the low apes the gain to the parietal area, by the shortness of the frontal lobe, is more than compensated for by the great size of the occipital lobe.

The fronto-Rolandic indices which I have obtained for the human brain at different periods of growth (p. 176), and also for the ape brain, render it impossible for me to adopt the conclusions which have been arrived at by Mingazzini.* In a very exhaustive memoir upon the cerebral surface this author remarks: "From these observations it results that in the

* "Intorno ai solchi e le circonvoluzioni cerebrali dei Primati e del feto umano," Estratto dagli Atti della R. Acad. Med. di Roma. Anno XV., vol. IV., serie II. 1888.

gradual developmental predominance which the frontal lobe gains in comparison with the parieto-occipital portion of the cerebrum during the increase of the human brain and that of the primates, the same law of evolution is exactly reproduced which has regulated the development of the superficies of the mantle in the phylogenesis of the primates. Inasmuch as the greater development of the frontal brain, in comparison with the parieto-occipital, distinguishes the brain of man from that of the other primates, of the adult from that of the fœtus, of the male from that of the female, of the intelligent from that of idiots, it is reasonable to suppose that this fact ought to be established as one of the fundamental characteristics of the psychic evolution in the primates and in man." In so far as we can judge the size of the frontal lobe by tape measurement, it is not relatively greater in the adult than in the fœtus, nor in the male than in the female; and further, although the frontal lobe is extremely small in all apes, still in the anthropoid apes it is, in its upper part, relatively longer than in man. It appears to me that the parietal and occipital lobes throughout the order Primates are equally distinctive.

In the foregoing Table the relations presented by the fissure of Rolando to the cranial wall are also expressed by a series of corono-Rolandic indices. In the chimpanzee the upper corono-Rolandic index (16) is very nearly in accord with the corresponding index in man (16·7). The position of the upper end of the fissure, therefore, with reference to the bregma, is relatively the same in both. In the orang the distance between the suture and the upper end of the sulcus is relatively much greater, as evidenced by the index of 20·7. In the chimpanzee the lower end of the fissure approaches much more closely to the coronal suture (index 7·5) than in man (index 12·9), or in the orang (index 11·1). The position of the fissure of Rolando, with reference to the coronal suture in the chimpanzee and orang, is exhibited in Plate VIII.

As might be expected, we find that in the lower apes of the old world the fissure of Rolando throughout its whole length lies nearer to the coronal suture than in man. In Plate VIII. these relations are exhibited in the macaque and baboon.

In Cebus the relations of the fissure of Rolando to the cranial wall

are altogether peculiar. These may be studied in Plate VIII., in which a model of the head of a *Cebus capucinus*, with the brain exposed *in situ*, is depicted. In the cranium of this animal the coronal suture is extremely oblique, and the bregma is placed very far back. In consequence of this the suture crosses the upper portion of the fissure, and the upper end of the latter, therefore, comes to lie a short distance *in front* of the bregma. The index obtained is 5·3. Further, owing to the straight course pursued by the fissure, it comes about that its lower end is placed very far behind the coronal suture. The lower corono-Rolandic index is no less than 16·3. Feré * has also called attention to the unusual relations presented by the fissure of Rolando to the cranial wall in Cebus.

VII. **Rolandic Angle.**—By the "Rolandic angle" I mean the angle which is formed by the meeting of the upper end of the sulcus with the mesial plane. If we were to divide a cerebral hemisphere into an anterior and posterior portion along a line stretching from the point where the sulcus oversteps the upper border of the hemisphere to the lower end of the fissure, the angle which would then be formed by the cut surface and the mesial surface of the anterior segment would constitute the Rolandic angle.

Several authors have sought to establish a sexual distinction by means of this angle. Huschka remarks: "On an average the fissure of Rolando, with its bounding central convolutions, stands more perpendicularly in the female than in the male." Rüdinger says: "The more transverse direction of the fissure of Rolando, and the bounding central convolutions, appears in the female fœtal brain a striking arrangement. But as the oblique direction of the central convolutions in the female fœtal brain, and the transverse in the male, likewise occur, I might provisionally entertain the supposition that these differences might be produced less through sex than through differences in the shape of the head." His pupil, Passet, is less cautious, and states dogmatically that "the angle which the fissure

* "Contribution à l' étude de la topographie cranio-cérébrale chez quelques singes," Journal de l' Anat. et Hist., vol. xviii.

of Rolando forms with the mesial plane is greater in the female and approaches more nearly to a right angle than in the male; in other words, the male fissure of Rolando, on an average, courses somewhat more obliquely from above downwards and outwards than in the female." This author represents the average male angle to be 60°·9, and the average female angle as 64°·2. More recently Dr. Josef Victor Rohon,* another worker in the laboratory of Professor Rüdinger, goes so far as to assert that the same sexual distinction in the angle of Rolando may be detected in the chimpanzee.

Giacomini gives the angle of the fissure of Rolando as varying from 57°·5 to 62°·5, whilst Hare,† who measured it *in situ*, found it to vary from 60° to 73°, the average being 67°. Eberstaller, on the other hand, who examined no less than 300 hemispheres, states that the Rolandic angle varies from 70° to 75°, and that he could discover no sexual difference in this respect. To quote his own words: "Meine Messungen, die sich auf rund 300 Hemisphären erstreckten, ergaben nun fast constant einen Winkel von 70°–75°; einen nennenswerthen Geschlechts-unterschied konnte ich nicht constatiren."

To measure this angle correctly is a matter of very great difficulty, and therefore we need not be surprised that the various authors I have quoted should have arrived at such divergent results. A very simple instrument, which I had constructed for the purpose, enabled me, I believe, to measure the angle accurately. Two straight, narrow, and flexible bands of brass were jointed together in the manner described and figured in page 132. In adjusting the instrument the long strip of brass was bent over the middle line of the head from the glabella in front to the external occipital protuberance behind, and in such a position that the joint between the two bands of metal was placed immediately behind the point at which the fissure of Rolando overstepped the mesial border of the hemisphere. The short limb of the instrument was then bent round the surface of the cerebrum, and moved until its anterior border corresponded to the general direction of the fissure. The angle was thus secured, and, after tracing it

* Zur Anatomie der Hirnwindungen bei den Primaten. München, 1884.

† "The Position of the Fissure of Rolando," Journ. Anat. and Phys., vol. xviii., p. 717.

on paper, it was measured in the ordinary way. In the fœtal and very young brains the angle was ascertained on hemispheres removed from the cranial cavity, and specially prepared with the view of preserving the external configuration. For these the instrument was equally serviceable. The following are the results I obtained:—

Rolandic Angle.

Age.	Number of Hemi-spheres.	Average Angle in Males and Females.	Limits of Variation.	Males.			Females.		
				Number of Hemi-spheres.	Average Angle.	Average Cephalic Index.	Number of Hemi-spheres.	Average Angle.	Average Cephalic Index.
Intrauterine Life—									
5½ to 6½ months, .	8	73°·6	72° to 79°	—	—	—	—	—	—
6½ to 7½ months, .	6	73°·5	70° to 79°	—	—	—	—	—	—
7½ to 8½ months, .	16	70°·8	65° to 80°	5	74°·4	—	11	69°·3	—
Full-time fœtuses,	16	70°·6	68° to 75°	13	70°·1	—	3	73°	—
Extrauterine Life—									
First 12 months, .	9	70°·6	65° to 76°	—	—	—	9	70°·6	76·2
4 to 5 years, . .	5	70°·6	68° to 73°	4	70°	77·7	1	73°	81·5
11 to 15 years, .	7	70°·1	68° to 74°	4	71°·2	76·1	3	69°	74
Adult, ...	8	71°·7	69° to 74°	3	73°·6	79·7	5	71°·7	74
Chimpanzee, . .	4	68°	—	—	—	—	—	—	—
Orang, ...	4	68°	—	—	—	—	—	—	—
Hamadryas, . .	1	71°	—	—	—	—	—	—	—

72.4 77.9 70.4 74

From the above Table it would appear that the average Rolandic angle in the adult may be regarded as being 71°·7. The results which I have obtained in this respect closely correspond with those stated by Eberstaller. As we have seen, this authority states that in the adult the angle varies from 70° to 75°. I have found the limits of variation to be 69° and 74°. Further, it will be observed that the average angle may almost be said to be attained as early as the eighth month of fœtal life, and is maintained from this period up to adult life—another remarkable instance of the

fixity of the fissure of Rolando, once its preliminary development is fairly established. In the first two months of its existence the Rolandic fissure presents a more open angle with the mesial plane. It traverses the surface of the hemisphere in a more transverse direction (73°·6). Mingazzini * has noticed this point. He says: "In the human fœtus of the sixth month the fissure of Rolando is nearly perpendicular, and with its development it gradually becomes more oblique." In several of the fœtal brains which I examined, the angle reached 79° and 80°. Hamy, in a Paper already referred to, contends that in the young subject the Rolandic angle is only 52°, whilst in the adult it is 70°, and he seeks to associate this with the development of the third frontal convolution. It is needless to say that there is no foundation whatever for this statement.

As might be expected from what we have seen in regard to the position of the upper and lower ends of the fissure of Rolando in the anthropoid cerebrum the Rolandic angle is more acute in the orang and the chimpanzee than in man. In the lower apes it is as a rule more obtuse; but it may be (as for example in Hamadryas) very similar to the angle in the human brain.

Hamy † considers that striking differences in the inclination of the fissure of Rolando may be noted in the brains of young and old apes belonging to the same species. I strongly suspect that these differences are merely individual and do not bespeak growth changes. In a young chimpanzee he remarks that the angle was 64°, whilst in one considerably older it was 68°. Again, in the macaque he states that it increases from 62° to 70°.

Nor is there anything in the angle of the fissure of Rolando by which we can establish sexual distinctions. I quite agree with Eberstaller in this. The above Table shows differences, it is true, but the increase or diminution of the angle is as often found on the one side as the other. How can we account for these differences? Rüdinger was not far from the truth when he hinted that the form of the head might have some influence

* "Intorno ai solchi e le circonvoluzioni cerebrali dei Primati e del feto umano." Estratto dagli Atti della R. Accad. Med. Roma, Anno. xv., vol. iv., serie ii., p. 15.

† "Contribution à l'étude du développement des lobes cérébraux chez les Primates," Archiv. de Zool. exper. et gen. 1872, pp. 430 and 431.

in this direction. Anyone who studies the average cephalic indices which I have introduced into the Table will see that the angle increases and decreases with the rise and fall of the cephalic index.* In brachycephalic heads the angle is more open than in dolichocephalic heads. In the first twelve months of extrauterine life all the specimens I examined were from females. Collectively they present the average angle of 70°·6, but if we analyze the various items which go to form the whole, we find three hemispheres with an average angle of 67°·7, and the unusually low cephalic index of 71, whereas the others gave an average angle of 73° and an average cephalic index of 79.

It is right to state that the results obtained by Mr. Hare do not coincide with this view, and from the fact of his measurements having been made upon the brain *in situ* I attach a high importance to them. In five dolichocephalic heads the average angle was 68°·6, whilst in six brachycephalic heads it was 66°·6.

VIII. **Length of the Fissure of Rolando.**—Passet has endeavoured to prove that the fissure of Rolando is both relatively and absolutely longer in the male than in the female, and Rohon believes that the same sexual distinctions may be detected in the chimpanzee. The absolute length of the fissure is of no importance, because this will vary with the absolute size of the brain, and therefore the increase in length in the male is what might naturally be expected. In order to get at the relative length, it is necessary to have some standard wherewith we may compare it. As the most convenient standard I have taken the total length of the hemisphere measured by the tape along its superior border. This we shall regard as being equal to 100. The fissure was measured by a thread introduced between the lips of the fissure and following accurately all its flexures.

My results are very different from those obtained by Passet. It appears to me that three circumstances affect the length of the fissure:—(1) the

* Welcker, Broca, and Calori hold that the head of the female is more dolichocephalic than that of the male. If this be the case, we would expect to find a more acute Rolandic angle. Weisbach, Arnold, and Mantegazzi, on the other hand, consider that it is the male head that shows the greatest amount of dolichocephaly.

depth of the portion of the cerebrum which lies above the Sylvian fissure; (2) the degree of flexuosity of the fissure; and (3) the union or non-union of the fissure with the inferior transverse furrow of Eberstaller. The following are my results:—

Length of the Fissure of Rolando.

	Age.	Number of Hemi-spheres.	Average Relative Length (Male and Female).	Males.		Females.	
				Number of Hemi-spheres.	Average Relative Length.	Number of Hemi-spheres.	Average Relative Length.
Intrauterine Life.	5½ to 6½ months, ...	8	16·7	—	—	—	—
	6½ to 7½ months, ...	6	25·1	—	—	—	—
	7½ to 8½ months, ...	10	35·4	2	29·7	8	36·8
	Full-time fœtuses, . . .	11	32·8	10	33	1	31
Extrauterine Life.	First 12 months, ...	8	35·8	—	—	8	35·8
	4 to 5 years, ...	7	33·9	5	33·4	2	38·5
	11 to 15 years, ...	6	36·1	4	33·7	2	38·9
	Adult, ...	30	39·3	14	38·6	16	40·1
	Chimpanzee, ...	4	51·1	—	—	—	—
	Orang, ...	4	47·2	—	—	—	—
	Hamadryas, ...	1	41·1	—	—	—	—

From this Table it is clear that if there is any sexual distinction to be discovered in the relative length of the fissure of Rolando, it is quite in the opposite direction from that stated by Passet and Rohon. My own belief is, that the length of the fissure is considerably affected by the shape of the head, and that in brachycephalic individuals it is relatively longer than in dolichocephalic individuals.

The great relative length of the fissure in the anthropoid apes is remarkable. This is partly explained by the fact, that in the chimpanzee and orang there is relatively more brain surface above the fissure of Sylvius than in man (*vide* p. 144). Further, the anthropoid fissure is more flexuous.

IX. **Summary.**—1. Rolando was not the first observer who described the fissure which bears his name, and it was only through an accidental circumstance that his name became associated with it.

2. In 60 per cent. of the brains examined the upper end of the fissure of Rolando turned over the mesial border of the hemisphere, and appeared on the mesial surface; in 19 per cent. its lower end presented a shallow connexion with the fissure of Sylvius.

3. This latter connexion was established by means of the inferior transverse sulcus of Eberstaller.

4. The fissure of Rolando is developed in two pieces. Its lower two-thirds appear first, and its upper third at a later period, and quite independently.

5. In very rare cases these two pieces do not unite, and then a superficial gyrus connects the ascending frontal and ascending parietal convolutions.

6. As a general rule, in the adult brain, some trace of the double origin of the fissure of Rolando persists. At the point of union there is usually a shallowing of the fissure, with either an interlocking of the boundary banks, or, perhaps, a distinct deep annectant gyrus.

7. The fissure of Rolando, in its development, therefore corresponds with the other two radial "Primärfurchen." They are all (*i. e.* præcentral, the fissure of Rolando, and the postcentral) developed in two pieces.

8. The inferior genu of the fissure of Rolando usually makes its appearance before the superior genu.

9. After the fissure of Rolando is fairly laid down, the posterior bounding-bank (*i. e.* the ascending parietal convolution) shows a greater growth energy than the anterior bounding-bank (*i. e.* the ascending frontal convolution).

10. The stability of position of the fissure of Rolando on the surface of the cerebrum, at all periods of growth, is remarkable. In the adult the upper fronto-Rolandic index is 53·3, and the lower 43·3. The only period of development at which there is a marked deviation from this is between the sixth and the eight months of intrauterine life, when the upper end of the fissure is placed further back.

11. The relative position of the fissure of Rolando, on the surface of the cerebrum, is the same in the two sexes, and also in the two hemispheres.

12. The parietal bone, and the area of brain immediately subjacent, do not grow at an equal pace. In the early stages of its development the fissure of Rolando lies close to the coronal suture, but this does not mean that it lies far forward on the brain, but simply, that the parietal bone forms, at a later stage, a relatively greater extent of the cranial vault.

13. The position of the fissure on the surface of the cerebrum is more fixed than the position of the coronal suture on the cranial vault at different periods of growth.

14. In the anthropoid apes the upper end of the fissure of Rolando is placed relatively further back on the cerebrum than in man.

15. The average Rolandic angle in the human brain is 71°·7. There is no sexual difference in this respect, but it would appear that in brachycephalic heads the angle opens out, and in dolichocephalic heads it becomes more acute.

16. The average relative length of the fissure of Rolando in the adult human brain is 39·3. If there is any sexual distinction in this respect the fissure is relatively longer in the female that in the male. In all probability the variations in the relative length of the fissure are due to differences in the shape of the head.

CHAPTER IV.

THE INTRAPARIETAL SULCUS.

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I. **General Statement.**—The intraparietal sulcus was first described and named by Sir William Turner in a paper* upon the brain of the chimpanzee which was submitted to the Royal Society of Edinburgh on the 19th of February, 1866. In the following month he demonstrated its connexions in the human brain in a lecture† which he delivered to the Royal Medical Society in Edinburgh. In the same year, but somewhat later, the fissure was also independently described by Dr. Adolf Pansch of Kiel,‡ under the name of sulcus parietalis. Prior to the excellent descriptions which are given by both of these anatomists the intraparietal sulcus had been accurately figured, not only in the brain of the apes, but also in the brain of man.

In the cerebrum of certain of the lower apes the intraparietal sulcus is single, and uninterrupted throughout its whole course; in man, however,

* "Notes more especially on the Bridging Convolutions in the Brain of the Chimpanzee," Proc. Roy. Soc. Edinburgh, 19th February, 1866.

† The Convolutions of the human cerebrum topographically considered," Edinburgh Medical Journal, June, 1866; also as a separate publication. Edinburgh, 1866.

‡ De sulcis et gyris in cerebris simiarum et hominum; Kiliae, 1866, vi., i., p. 9.

it has become broken up into three more or less distinct parts, whilst a new factor has been superadded. The term "intraparietal," therefore, as applied to the human brain, includes not one sulcus but a system of sulci. Of the different factors which go to form the intraparietal sulcus in man, we recognize: 1, a vertical part which separates the supramarginal convolution from the ascending parietal convolution, and stands parallel to the lower portion of the fissure of Rolando; 2, a horizontal portion which stretches backwards in a more or less horizontal direction between the superior and inferior parietal lobules; and 3, a continuation of this into the occipital region which bounds externally the first annectant gyrus. The fourth element which has been superadded, and which has not resulted from the disruption of the originally single sulcus, consists of a short vertical limb which intervenes between the superior parietal lobule and the upper part of the ascending parietal convolution.

The description which was given by Sir William Turner of the intraparietal sulcus in the human brain has been in all its essential features adopted by the anatomists of this country. The three disrupted parts of the originally single fissure are represented as being in the adult, superficially at least, continuous, whilst the fourth superadded element is represented as remaining separate. Leaving out of count for the present the relations which the intraparietal sulcus establishes in the occipital lobe, the description is all that could be desired from a morphological point of view. The triple constitution of the parietal part of the sulcus is clearly indicated, whilst occipital connexions are hinted at which are of the highest interest and importance. It fails, however, in so far that the arrangement of the three parietal limbs which is detailed is not the usual one. There are several varieties of the intraparietal sulcus. The one which is referred to in the above description only occurs in 19·1 per cent. of adult cerebral hemispheres. All the different varieties of the sulcus can be explained and understood by a reference to its mode of appearance in the fœtal brain and to its condition in the brain of the apes.

For convenience in description it is necessary that we should apply special terms to the different factors which go to form the intraparietal system of sulci. The two vertical limbs which together bound posteriorly

the posterior central or ascending parietal convolution we may distinguish as the *sulcus postcentralis inferior* and the *sulcus postcentralis superior*. The horizontal parietal portion we shall designate the *ramus horizontalis ;* whilst the occipital part may be termed the *ramus occipitalis*. Ecker* gives to the continuous fissure which so frequently results from the union of the two vertical sulci the name of sulcus postcentralis. Mihalkovics,† on the other hand, calls it the sulcus retrocentralis. To the ramus horizontalis Ecker applies the term sulcus interparietalis, and to the ramus occipitalis the name of sulcus occipitalis longitudinalis superior. The latter term is very unwieldy, and does not sufficiently bring out the fact that the sulcus in question is merely a factor, from both the ontogenetic and phylogenetic points of view, of the intraparietal system. The term "interparietal" as a synonym for the horizontal parietal limb is undoubtedly good, seeing that this portion of the sulcus intervenes between the superior and inferior parietal lobules, but it has the great disadvantage of being very similar to the general name applied to the group of furrows which make up the whole system. At the same time I am fully alive to the objection which may be raised against the term which I propose to substitute for it, viz. that the sulcus in question is very rarely exactly horizontal; in the great majority of cases it is somewhat oblique in its direction.

I do not think that the retention of the term "intraparietal" as originally proposed by Sir William Turner for the entire system of furrows requires any defence. All its constituent parts lie within the limits of the parietal lobe with perhaps the exception of the hinder end of the ramus occipitalis; and if we accept the limitations of the occipital lobe which have been advocated by Eberstaller‡ the entire length of even the ramus

* Ecker, "Zur Entwicklungsgeschichte der Furchen und Windungen der Grosshirn-Hemisphären im Fœtus des Menschen;" Archiv für Anthrop.; Dritte Band; Drittes und Viertes Heft, 1869.

† Entwicklungsgeschichte des Gehirns. Leipzig, 1867.

‡ Zur Oberflächen-Anatomie der Grosshirn-Hemisphären; vorläufige Mittheilung. II. Wiener Medizinische Blätter, No. 18, Mai, 1884. In this article Eberstaller holds that the anterior boundary of the occipital lobe is the sulcus transversus occipitalis of Ecker, which he believes to be the representative of the "Affenspalte" in the ape's brain.

occipitalis is included within the parietal area. Such being the case it appears to me that the term is singularly appropriate, and should be preserved on this account as well as on the ground of priority.

It will therefore be understood that I do not agree in any respect with the following remarks which appear in Pansch's work upon the convolutions and furrows of the central hemispheres:—"*Sulcus parietalis* ist die seiner Zeit von mir gegebene Bezeichnung, die ich heute noch für die einfachste und logisch richtigste halte auch wenn man die üblichen Hirnlappen annimmt. Das '*intra*' ist ein unnöthiger Zusatz; keinenfalls aber liegt eine Veranlassung vor, die Turner'sche Bezeichnung in *interparietalis* umzuwandeln."* The attack upon Ecker's term, "interparietalis," is altogether undeserved, because this author has never expressed the desire to apply that name to the entire system of furrows under consideration. He only seeks, as we have noted, to give it to one portion of the fissural system, viz. to the ramus horizontalis.

II. **Development of the Intraparietal Sulcus.**—The development of this sulcus affords us one of the most beautiful examples of the interrupted mode of furrow-formation which is present in the human brain. Further, as we shall see later on, there appears to be some ground for the view that in the process of its evolution the disruption of an originally single and continuous fissure has taken place.

The formation of the intraparietal sulcus in the fœtal brain presents so much variability in different specimens that it is a difficult matter to decide upon what is in reality the typical arrangement of its several parts. The details which I give under this head are derived not only from the examination of the large number of fœtal brains in my possession but also from a study of the masterly memoirs of Ecker,† and Pansch,‡

* Die Furchen und Wülste am Grosshirn des Menschen, p. 14. Berlin, 1879.

† Ecker, "Zur Entwicklungsgeschichte der Furchen und Windungen der Grosshirn-Hemisphären im Fœtus des Menschen;" Archiv für Anthrop.; Dritte Band; Drittes und Viertes Heft, 1869.

‡ Pansch, "Ueber die typische Anordnung der Furchen und Windungen auf den Grosshirn-Hemisphären des Menschen und der Affen," Archiv für Anthrop., 1869.

and of the plates which accompany the writings of Reichert,* and Bischoff.†

Ecker considers that the sulcus intraparietalis first makes its appearance in the sixth month of fœtal life in the form of two parts, viz. an anterior and a posterior. These are genetically distinct and represent the interparietal (ramus horizontalis) and occipital portions of the furrow. In the seventh month the postcentral sulcus comes into view, but he makes no mention of its double constitution.

Mihalkovics ‡ holds somewhat similar views. He says: "In the sixth month the sulcus interparietalis consists of two separate parts. . . . In the seventh month the sulcus retrocentralis makes its appearance. In the eighth month the confluence of the two parts of the interparietal sulcus occurs."

Pansch gives a very concise, and, as far as it goes, accurate account of the typical arrangement of the different parts of the intraparietal sulcus in the fœtal brain. To use his own words: "Sie setzt sich mitunter in gerader Richtung weit nach oben fort, parallel der zweiten radiären Primärfurche, oder sie endet schon auf halber Höhe und jene Fortsetzung findet sich in einer isolirten Furche angedeutet, oder sie setzt sich in einem Bogen nach hinten fort, so dass sie schliesslich dem innern Rande der Hemisphäre parallel liegt, oder wiederum auch dieser Theil erscheint isolirt, entweder zugleich mit jenem obern Fortsatz oder ohne denselben. Also auch hier, wenn denn doch einmal ein sogenannter allgemeiner Typus aufgestellt werden soll, wird man einen 'Stamm,' einen 'obern Ast,' und einen 'hintern Ast' der dritten radiären Primärfurche annehmen dürfen." The third radial primary furrow to which he refers is the intraparietal sulcus; the stem is the sulcus postcentralis inferior; the upper branch is the sulcus postcentralis superior; and the hinder branch is the ramus horizontalis.

From the observations which I have made I am inclined to regard none of the foregoing descriptions of the development of the intraparietal sulcus

* Reichert, Der Bau des menschlichen Gehirns. Leipzig, 1861.

† Bischoff, "Die Grosshirnwindungen des Menschen," aus den Abhandlungen der k. bay. Akad. der Wiss., 11. Cl., x. Band., 11. Abth.

‡ Entwicklungsgeschichte des Gehirns, p. 154. Leipzig, 1877.

as absolutely satisfactory. I do not agree with Ecker and Mihalkovics in considering it usual for the two hinder portions of the sulcus to appear earliest on the field. As a rule it is the sulcus postcentralis inferior which first shows itself, and its development is clearly associated with that of the fissure of Rolando and the præcentral furrow, as well as with the three primitive sulci on the surface of the island of Reil. The more usual order of formation is the fissure of Rolando first, then the præcentral furrow, and lastly the inferior postcentral sulcus. In some cases the præcentral sulcus precedes the fissure of Rolando, but I have only seen one hemisphere in which the sulcus postcentralis inferior was the earliest to appear on the cerebral surface. These three furrows constitute a group of sulci which radiate upwards from the Sylvian region, and, as a rule, they are all in place towards the end of the sixth month.

In its earliest condition the sulcus postcentralis inferior appears in the form of a broad shallow groove or depression, which is chiefly brought into view by the rise of the ascending parietal convolution. It is very rarely seen before the middle of the sixth month; in fact, it is usually developed in the second half of that month, or in the early part of the seventh (Pl. I., figs. 22, 25, and 24, *p.*; and Pl. II., figs. 13, 17, 18, 19, and 20, $p.^1$).

At the end of the sixth month, or more usually at the commencement of the seventh month, the ramus horizontalis and the ramus occipitalis come into view. It is difficult to decide which has the priority in point of development. If there is any difference it is in favour of the ramus occipitalis. Certainly it is this furrow which, as a general rule, assumes in the early condition of both the greatest depth and forms the most decided impression on the cerebral surface (Pl. II., figs. 17, 19, and 20, $p.^3$ and $p.^4$). It is very rare to find a cerebrum in which the one is developed before the other (Pl. II., fig. 18, $p.^3$).

The ramus occipitalis is closely associated with the appearance of the parieto-occipital fissure on the outer surface of the hemisphere. As the upper end of the latter begins to show in the form of a broad groove on the mesial border of the hemisphere, the ramus occipitalis comes into existence and marks off the portion of the cerebral surface which ultimately forms the first annectant gyrus. It takes the form, therefore, of a curved sulcus

running in the sagittal direction, with its convexity directed outwards, and its extremities slightly bent inwards in front and behind the upper end of the parieto-occipital fissure.

At first the ramus horizontalis and the ramus occipitalis stand well apart, but as they extend they gradually approach each other, and finally establish a superficial connexion. This confluence, although the rule, fails in many cases, so that even in the adult the two sulci may still be found distinct and separate. According to Mihalkovics the union of these two elements takes place at the eighth month. But this is by no means an invariable rule, because the connexion is in many cases delayed until after birth. Thus, in fœtuses of the eighth month, I found the two sulci still separate in 66·7 per cent. of the hemispheres examined; in full-time fœtuses in 42·2 per cent.; and in the adult in 36·3 per cent.

But the ramus horizontalis extends forwards as well as backwards, and the result is that a union is usually effected with the upper end of the sulcus postcentralis inferior. This coalescence when it occurs takes place early in the eighth month, although the deep annectant gyrus which marks the junction remains very high until the time of birth.

There are many instances, however, in which the ramus horizontalis is developed in direct continuity with the sulcus postcentralis inferior. In these cases the upper end of the latter arches backwards, so as to occupy the ground usually held by the ramus horizontalis. This is a reversion to the primitive type (Pl. I., fig. 31, $p.^1$ and $p.^3$), and is the mode of development which Pansch considered to be the most common. The arching fissure which results gives no indication of that tendency to the divorce of the horizontal ramus from the postcentral sulcus which is so marked a characteristic of the human brain.

Lastly, the upper part of the postcentral sulcus (sulcus postcentralis superior) makes its appearance in the form of a shallow depression placed between the mesial border of the hemisphere and the superior end of the sulcus postcentralis inferior. It is in every respect comparable with the upper piece of the fissure of Rolando and the sulcus præcentralis superior (Plate II., figs. 17, 18, and 24, $p.^2$). Reichert includes this part of the intraparietal sulcus, as well as the ramus occipitalis, amongst the

"peripherischen Primärfurchen." It may remain distinct and separate, but more frequently it extends downwards, and joins the sulcus postcentralis inferior.

There are many variations to be noted in the mode in which the intraparietal sulcus developes. For example, there appears to be a tendency towards the still further break-up of its several elements. Thus, the sulcus postcentralis inferior, the ramus horizontalis, or the ramus occipitalis, may each appear in the first instance in the form of two depressions which ultimately run into each other. The bifurcation of the upper end of the parieto-occipital fissure, and the appearance of the two resulting branches on the mesial border of the hemisphere seems to be usually, or at least very frequently, associated with a duplication of the developing ramus occipitalis.

From what has been said, it will be seen that Eberstaller,* in his admirable account of the intraparietal sulcus, is justified in applying to it the term, "Furchenconglomerat." Further, this author has rightly called attention to the fact that a third element may be added to the postcentral part of the fissure. This he terms the sulcus retrocentralis transversus. It is a small furrow which cuts the margin of the fronto-parietal operculum, and stands in the same relation to the postcentral sulcus as the sulcus centralis transversus to the fissure of Rolando (p. 164). To quote his own words: "Dieser Sulcus retrocentralis transversus bedingt durch seine Richtung die dreieckige Verbreiterung des unteren Endes der hinteren Centralwindung, bricht aber in seltenen Fällen mit seinem oberen Ende sogar in die Rolands-spalte durch und überschreitet mit seinem unteren Ende häufig die Opercularkante, so dass der Ursprung des Gyrus supramarginalis aus der hinteren Centralwindung mehr weniger tief eingedrückt wird . . . Fliessen alle drei beschriebenen Einzelbestandtheile der Retrocentralfurche zusammen, so gibt das eine der Centralspalte parallele, von der Mantelkante bis zur Sylvischen Spalte schräg nach unten und vorne ziehende Furche."

This lower piece of the postcentral sulcus, the sulcus postcentralis transversus of Eberstaller, does not appear until the middle of the eighth month

* Zur Oberflächen-Anatomie der Grosshirn-Hemisphären. Wiener Medizinische Blätter, No. 20, 1884, p. 612.

(Pl. IV., fig. 1, *i. p.*), and in those cases where it joins the sulcus postcentralis inferior above, and turns round the opercular border below, it brings about a junction between the intraparietal sulcus and the Sylvian fissure. This confluence occurred in about 25 per cent. of the adult hemispheres examined, but in every case the point of union with the sulcus postcentralis inferior was indicated by the presence of a deep annectant gyrus.

III. **Intraparietal Sulcus in the Apes.**—The morphological importance of the different elements of the intraparietal sulcus can best be appreciated by an appeal to the brain of the apes. By this means we can accord to each its proper value.

In the great majority of the lower apes the most apparent part of the intraparietal sulcus is present in the form of a sharply-cut oblique fissure, which traverses the parietal lobe from its antero-inferior angle to its postero-superior angle. Here it bends round the upper part of the angular convolution, and comes to an end. Its mode of termination differs considerably in different members of the group, and will be studied more fully in another part of this chapter. This continuous fissure represents the sulcus postcentralis inferior, the ramus horizontalis, and the ramus occipitalis of the human brain.

The sulcus postcentralis superior is in many apes, as for example, *Cebus capucinus* and *Cebus albifrons*, entirely unrepresented. In nine cerebral hemispheres taken from these two species, I could not detect the slightest trace of this furrow. In the baboon, the macaque, and many other old-world apes, it is invariably present. It may take the form of a stellate depression behind the upper part of the fissure of Rolando, or it may be present in the shape of a shallow linear furrow. Both conditions are met with in the baboon (fig. 47, *e.*, p. 224, also Pl. IV., fig. 8); and in three of the fourteen hemispheres taken from this form which I have before me, the sulcus postcentralis superior extends downwards, and effects a junction with the main part of the fissure, thereby indicating a subdivision of the latter into two portions corresponding to the ramus horizontalis and the sulcus postcentralis inferior of the human cerebrum (Pl. IV., fig. 8, $p.^1$ and $p.^2$). In the macaque it is more usual for the sulcus postcentralis superior

to assume the linear form, but, although this is the case, it would appear that its junction with the main part of the fissure is not so common as in the baboon. In ten hemispheres the confluence only took place in one.

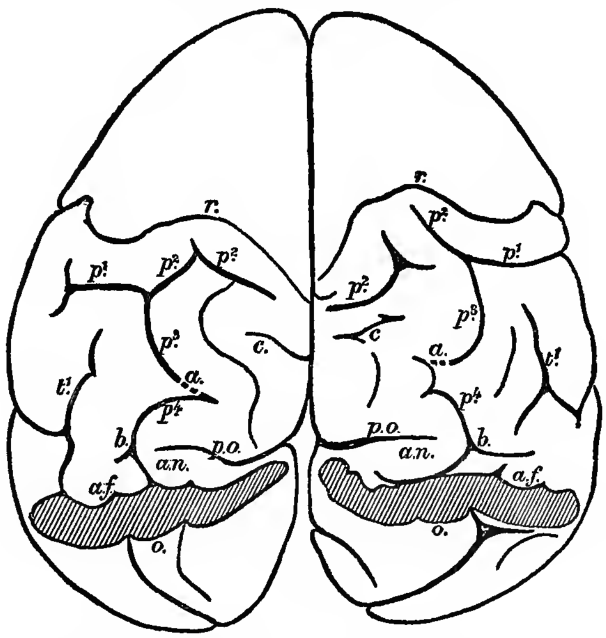


FIG. 35.—The cerebral hemispheres of a young female chimpanzee as seen from above. The occipital operculum on each side has been removed. Drawn by the American apparatus for tracing orthogonal projections of the skull. The brain was adjusted in the apparatus, so that its occipital end was very much higher than its frontal end, in order that the parts under cover of the occipital operculum might be introduced into the figure.

r.	Fissure of Rolando.
*p.*1	Sulcus postcentralis inferior.
*p.*2	Two portions of sulcus postcentralis superior.
*p.*3	Ramus horizontalis.
*p.*4	Ramus occipitalis.
b.	Terminal bifurcation of the intraparietal sulcus, *i.e.* Ecker's sulcus transversus occipitalis.
p.o.	Parieto-occipital fissure.
a.n.	First parieto-occipital annectant gyrus.
a.	Deep annectant gyrus in the course of the intraparietal sulcus.
c.	Secondary sulcus in the superior parietal lobule.
a.f.	Bottom of the "Affenspalte."
o.	Cut surface of the occipital operculum.
*t.*1	Parallel sulcus.

When we come to the anthropoid apes we find the union of the sulcus postcentralis superior with the main furrow much more common. This appears to be the usual condition in the chimpanzee and the gibbon. In six hemispheres of the former I find the sulcus postcentralis superior

separate in two (figs. 35 and 36), whilst in all the drawings of the chimpanzee brain at my disposal the union of the two portions of the postcentral sulcus is depicted. Two hemispheres of the gibbon presented the

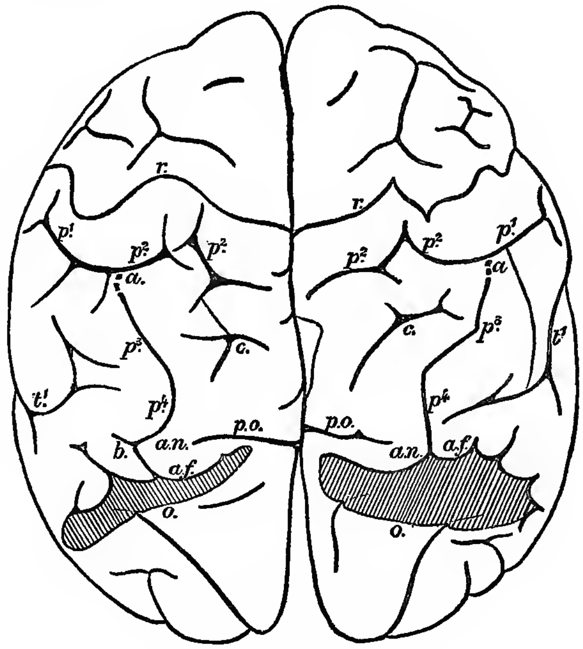


FIG. 36.—The cerebral hemispheres of a young female chimpanzee as seen from above. The occipital operculum on each side has been removed. Drawn by the American apparatus for tracing orthogonal projections of the skull. The brain was adjusted in the apparatus, so that its occipital end was very much higher than its frontal end, in order that the parts under cover of the occipital operculum might be introduced into the figure.

r. . . Fissure of Rolando.
*p.*¹ . . Sulcus postcentralis inferior.
*p.*² . . Two portions of sulcus postcentralis superior.
*p.*³ . . Ramus horizontalis.
*p.*⁴ . Ramus occipitalis.
b. . . Terminal bifurcation of the intraparietal sulcus, *i. e.* Ecker's sulcus transversus occipitalis.

p.o. . . Parieto-occipital fissure.
a.n. . . First parieto-occipital annectant gyrus.
a. . . Deep annectant gyrus in the course of the intraparietal sulcus.
c. . . Secondary sulcus in the superior parietal lobule.
a.f. . . Bottom of the "Affenspalte."
o. . . Cut surface of the occipital operculum.
*t.*¹ . . Parallel sulcus.

same confluence. Waldeyer informs us that in six hemispheres of this genus he noted the union in four cases, a failure of union in one, and an

absence of the sulcus postcentralis superior in the sixth.* Bischoff† also figures the union of the two postcentral furrows in the gibbon. In the orang the sulcus postcentralis superior appears in the majority of cases to remain separate, although in one figure by Bischoff‡ it is represented as being joined to the sulcus postcentralis inferior. In the gorilla it may present either condition,§ although it would seem that it is more frequently united than free.||

In the orang and the chimpanzee there is present a condition which seems to indicate that the sulcus postcentralis superior is composed of two pieces. In the former (fig. 37, p. 206) these elements ($p.^2$) are distinct and separate, and lie one above the other and in the same line as the sulcus postcentralis inferior before it turns backwards and becomes continuous with the ramus horizontalis. The condition of affairs in the chimpanzee is somewhat different, but leads to the same conclusion. In both hemispheres of each of the two chimpanzee brains depicted in figures 35 and 36, the lower of the two elements which apparently enter into the composition of the ramus postcentralis superior is directly continuous with the ramus postcentralis inferior, and the point of junction is indicated by the confluence of the ramus horizontalis; but above this there is a second upper element which is united with the lower piece in two hemispheres (viz. the left hemisphere in figure 35 and the right hemisphere in figure 36), whilst in the other two hemispheres it is distinct and separate. These latter are the two chimpanzee hemispheres which I have described as presenting a separate condition of the ramus postcentralis superior. In this assertion therefore I am only partially correct, inasmuch as its lower element in both cases is fused with the ramus postcentralis inferior.

* Das Gibbon-Hirn; "Internationale Beiträge zur wissenschaftlichen Medicin," Festschrift, Rudolf Virchow, &c., Band I., p. 42.

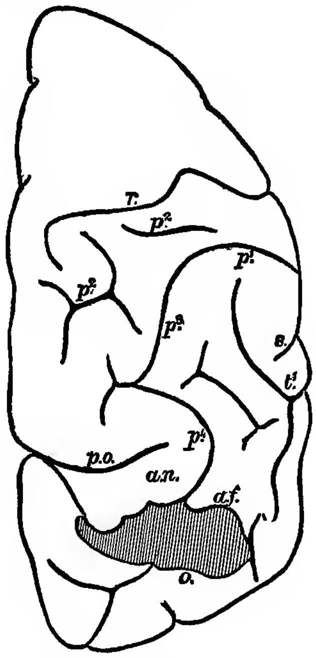
† "Beiträge zur Anatomie des Hylobates leuciscus," Pl. II., fig. 1, aus Abhandlungen der k. bayer. Akad. der Wiss., 11. Cl., x. Band., 3. Abth., 1870.

‡ "Ueber das Gehirn eines Orang-outan." Sitzung der Math.-Phys., Classe vom 17. Juni, 1876, k. bayer. Akad. der Wiss.

§ Broca, Mémoires sur le cerveau de l'homme; publiés par la Docteur S. Pozzi, p. 636.

|| Pansch, "Ueber die Furchen und Windungen am Gehirn eines Gorilla," Ueber die menschenähnlichen Affen des Hamburger Museums. Pansch und Bolau, Hamburg, 1876.

Further, the study of these anthropoid hemispheres suggests the proper interpretation to place upon the occurrence of a ramus postcentralis superior. It is merely one of a series of transverse secondary furrows which tend to appear on the ground above the primitive simple and continuous intraparietal sulcus (superior parietal lobule). These in the evolution



r. . . Fissure of Rolando.
p.^{1} . . Sulcus postcentralis inferior.
p.^{2} . . Two parts of sulcus postcentralis superior.
p.^{3} . . Ramus horizontalis.
p.^{4} . . Ramus occipitalis.
a.n. . . First parieto-occipital annectant gyrus.
p.o. . . Parieto-occipital fissure.
a.f. . . Bottom of the "Affenspalte."
o. . . Cut surface of the occipital operculum.
s. . . Fissure of Sylvius.
t.^{1} . . Parallel sulcus.

FIG. 37.—Right hemisphere of a male orang-utan about six years' old. The occipital operculum has been removed. Drawn by the American apparatus for tracing orthogonal projections of the skull. The hinder end of the hemisphere was raised considerably, in order that the parts under cover of the occipital operculum might be brought into view.

of the cerebral surface make their appearance in regular sequence from before backwards. The most anterior of the series comes into existence first, and when once fairly established it tends to join the ramus postcentralis inferior. It is the ramus postcentralis superior, and it affords an excellent example of how a furrow of secondary importance in a low form may assume a primary importance in a higher form. The others are very rarely seen in the lower apes; one or perhaps two occur in the chimpanzee, and, as a rule, they remain separate and distinct. In man they are more

numerous, and linking themselves on to the ramus horizontalis they constitute its upper secondary branches.

In the human fœtal brain I have only once seen the sulcus postcentralis superior appearing in two separate pieces. It is clear, however, that in the anthropoid brain the corresponding sulcus may have a double origin. In one cerebral hemisphere of a chacma baboon I have observed a similar tendency towards the duplication of the sulcus postcentralis superior (fig. 38).

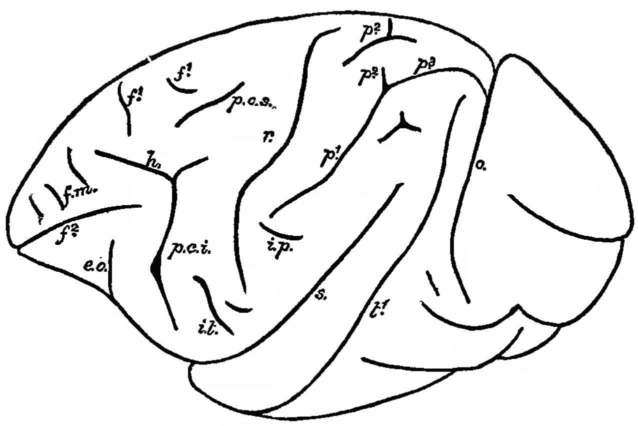


FIG. 38.—Left cerebral hemisphere of a Chacma baboon. Drawn by the American apparatus for tracing orthogonal projections of the skull.

p.	Various parts of the intraparietal system of furrows.	*p.*[3]	Ramus horizontalis.
p.[1]	Sulcus postcentralis inferior.	*i.p.*	Sulcus postcentralis transversus of Eberstaller.
p.[2]	Two parts of the sulcus postcentralis superior.	*o.*	Occipital operculum.

But it may be asked: Have we any trace in the apes of Eberstaller's third element of the postcentral sulcus, viz. the inferior transverse postcentral sulcus? In many of the low apes, as for example, Cebus, there is not a trace of it. In the macaque, in the baboon, and in some forms of Cercopithecus, it is very frequently present (fig. 38, *i.p.*). In ten hemispheres obtained from *Macacus rhesus* and *Macacus nemestrinus* it was detected in five; whilst in eleven hemispheres from the baboon it was noted in six. In both hemispheres of a specimen of *Cercopithecus griseoviridis*

it was also present. It is therefore not so constant in these apes as the corresponding element of the Rolandic fissure (p. 165).

Turning next to the anthropoid apes we find that in the chimpanzee and orang, Eberstaller's lower element of the postcentral sulcus is almost invariably present. In six hemispheres of the former and in four hemispheres of the latter it was very evident in every case. Further, it is not uncommon to find it composed of two small sulci—one placed above the other. When this occurs the upper piece may be united superficially with the sulcus postcentralis inferior—a distinct deep annectant gyrus marking the place of junction—whilst the lower piece may turn round the margin of the fronto-parietal operculum, and open into the Sylvian fissure. The same condition is occasionally seen in the macaque and baboon. Waldeyer* assures us, however, that Eberstaller's lower element of the postcentral sulcus is absent in the gibbon.

The *ramus occipitalis* of the intraparietal sulcus, as it is seen in the apes, presents some features of special interest; but it is better to defer the study of these until we deal with the corresponding segment of the fissure in the human brain.

Before turning from the intraparietal sulcus in the apes, we may as well point out that in Cebus, the baboon, and macaque, it is at least twice as deep as the fissure of Rolando. The latter furrow is, comparatively speaking, shallow. In the chimpanzee and the orang the difference in depth between these two sulci is not nearly so marked, although it is still very manifest that the intraparietal furrow is the deeper of the two. In the human brain the position of affairs is reversed, because although the intraparietal sulcus cannot be said to have lost anything in so far as its relative depth is concerned, the fissure of Rolando, in the great majority of cases, cuts more deeply into the cerebral surface. This is an interesting point in connexion with the law which Pansch so strenuously advocated, and which we shall give in his own words: "Die Vertiefung der Furchen im Laufe der Entwicklung findet im Allgemeinen ziemlich gleichmässig bei allen Furchen statt. Die zuletzt auftretenden Furchen bleiben stets flach,

* Das Gibbon-Hirn, Virchow's Festschrift. Band I., 1891.

die zuerst auftretenden werden stets tief. Man kann also am ausgewachsenen Hirn die Entwicklungsgeschichte der Furchen (Faltungen) einigermaassen ablesen, in dem man die Tiefe der Furchen untersucht." *

If we accept this proposition the relative morphological value attached to the fissure of Rolando and the intraparietal sulcus is different in man and in the ape, inasmuch as we must assume that the lower we descend in the primates the less becomes the importance attached to the fissure of Rolando, and the greater the value of the intraparietal sulcus. For my own part I am inclined to believe that this is really the case, but it is a question upon which it is difficult to offer a decided opinion, seeing that we are altogether ignorant as to the order in which these two furrows develope in the apes. The study of the phylogenetic evolution of the two furrows under consideration certainly points to the intraparietal sulcus as possessing a preponderating importance; and in connexion with this a paragraph in the address which was delivered in Berlin by Sir William Turner † presents the highest interest. Speaking of the fissure of Rolando he says:—"In the Prosimian Stenops and in *Lemur nigrifrons* it is absent. No vestige of it can be seen in the Platyrrhine marmoset; but it is distinct in the Platyrrhine genera Pithecia, Ateles, Cebus, &c. . . . It is true that the marmoset has a perfectly smooth cerebrum above and in front of the Sylvian fissure; but the hemisphere of Stenops possesses in its more anterior part rudimentary fissures extending antero-posteriorly, which mark the commencement of a differentiation into tiers of convolutions extending in a sagittal direction, such as one is familiar with in the frontal lobe of the higher apes. Corresponding antero-posterior fissures exist also in *Lemur nigrifrons*, and another fissure is placed further backwards, which is probably the homologue of the intraparietal fissure in the higher brains." The evidence thus afforded is decidedly in favour of regarding the intraparietal sulcus as possessing a greater phylogenetic antiquity than the fissure of Rolando.

Pansch was well aware of the greater depth of the intraparietal sulcus

* "Einige Sätze über die Grosshirnfaltungen," Centralblatt für die medizinischen Wissenschaften, No. 36, 1877, p. 643.

† Journal of Anatomy and Physiology, vol. xxv., p. 2.

in the apes, because in the Memoir in which he first described the fissure we find him making the following definite statement on the subject:—"Lobus igitur par hoc sulco, quem semper multo profundiorem quam fissuram Rolando invenimus, in duo dimidia fere aeque magna et similia dividetur." This observation refers to the sulcus in Cynocephalus, Macacus, and Cercopithecus.

IV. **Arrangement of the different elements of the intraparietal sulcus in the human brain.**—Putting aside for the present the ramus occipitalis (which we reserve for special notice), it is clear from the study of the brain of the apes, that two of the three remaining parts of the intraparietal sulcus, viz. the ramus horizontalis and the sulcus postcentralis inferior, are originally continuous and identical, whereas the third, the sulcus postcentralis superior, is an element which has been superadded, and may be looked upon as having an independent origin.

I have examined 127 human cerebral hemispheres, with the view of ascertaining the more usual disposition of the intraparietal sulcus. These comprised 63 adult Irish hemispheres; 8 adult negro hemispheres; 20 fœtal hemispheres about the eighth month of development; 17 full-time fœtal hemispheres; and 19 hemispheres obtained from children varying in age from the third month of infancy up to the twelfth year. Amongst these I found every possible form of combination of the three segments of the sulcus. No less than five varieties may be recognized.

VARIETY I.—*All three parts of the sulcus separate* (fig. 39).—It is very uncommon to meet with an adult cerebral hemisphere in which all the three segments of the sulcus are separated from each other by superficial and distinct bridging gyri.

Of the 127 hemispheres only 11 exhibited this condition, and the following list gives the percentage for each group:—

63 Adult hemispheres,	6·3	per cent.
8 Negro hemispheres,	12·5	,,
19 Children's hemispheres,	5·3	,,
17 Full-time fœtal hemispheres,	11·7	,,
20 Eighth-month hemispheres,	15	,,

This arrangement of the different parts of the intraparietal sulcus was, therefore, present in 6·3 per cent. of the adult Irish hemispheres examined. In the full-time and eighth-month fœtus the percentage is greater, which would seem to show that in certain cases the union of the different elements of the sulcus is delayed until after birth. It is interesting to note the high percentage for the negro brain. This indicates a fœtal condition; but seeing that it also bespeaks a greater number of superficial bridging gyri on the surface of the parietal lobe we cannot say that it is a degradation. Indeed, had it been present in the European brain probably the opposite conclusion would have been drawn.

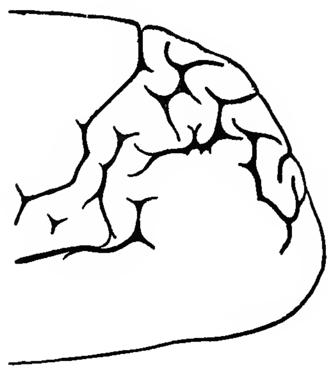


FIG. 39.—Posterior part of the left hemisphere of a young man twenty-five years old. The four factors of the intraparietal sulcus are all separate and distinct.

Sernoff,* who has also studied the disposition of the different parts of the sulcus in the adult, has found this arrangement rather more frequently in the Russian brain than I have observed it in the Irish brain.

VARIETY II.—*Ramus horizontalis confluent with the sulcus postcentralis inferior ; sulcus postcentralis superior separate* (fig. 40).—This is the condition of the intraparietal sulcus, which was originally described by Sir William Turner; and in the last edition of Quain's Anatomy it is given as the normal arrangement. The development of the fissure and the condition in

* Individualniye tipy mozgovykh izvilin u tchelovêka—(Individual types of the convolutions of the brain in man). Moscow, 1877, p. 34.

the apes would alike appear to indicate this variety as the typical one, but certainly it is not the most common. It was discovered in 27 of the 127 hemispheres examined.

63 Adult hemispheres, ...	19·1 per cent.
8 Negro hemispheres, ...	25 ,,
19 Children's hemispheres	26·4 ,,
17 Full-time fœtal hemispheres, ...	35·3 ,,
20 Eighth-month fœtal hemispheres, ...	10 ,,

The percentages which are given above, in a measure justify the statement which I have previously made in regard to the period at which the sulcus postcentralis superior joins the sulcus postcentralis inferior. In many cases it is evident that this union is delayed until after birth (*vide* 19·1 per cent. for the adult, 26·4 for the child, and 35·3 for the full-time

Fig. 40.—Left Hemisphere of a new-born Male Child. It shows the typical condition of the intraparietal sulcus.

fœtus). The low percentage for this variety in the eighth-month fœtus is difficult to explain, and is only partially accounted for by the high percentage for Variety I. (in which the sulcus postcentralis superior is also separate) in hemispheres at the same period of development.

Sernoff* has found this condition of the intraparietal sulcus in the adult Russian brain less frequently than I have noticed it in the Irish cerebrum.

Variety III.—*Postcentral sulci confluent; ramus horizontalis separate.*—A well-marked example of this variety of the fissure is represented in figure 41. At first sight the hemisphere appears to be traversed by two fissures of

* Individualniye tipy mozgovykh izvilin u tchelovêka. Moscow, 1877, p. 34.

Rolando and three central convolutions. The hinder of the two transverse sulci is the result of the complete union of the two vertical limbs of the intraparietal sulcus. It is the *sulcus postcentralis* of Ecker or the *sulcus postrolandicus* of Pansch divorced from the ramus horizontalis. A thick superficial bridging convolution which connects the superior parietal lobule and the supramarginal convolution cuts off the ramus horizontalis completely. No evidence as to its double nature can be gained by exploring the bottom of

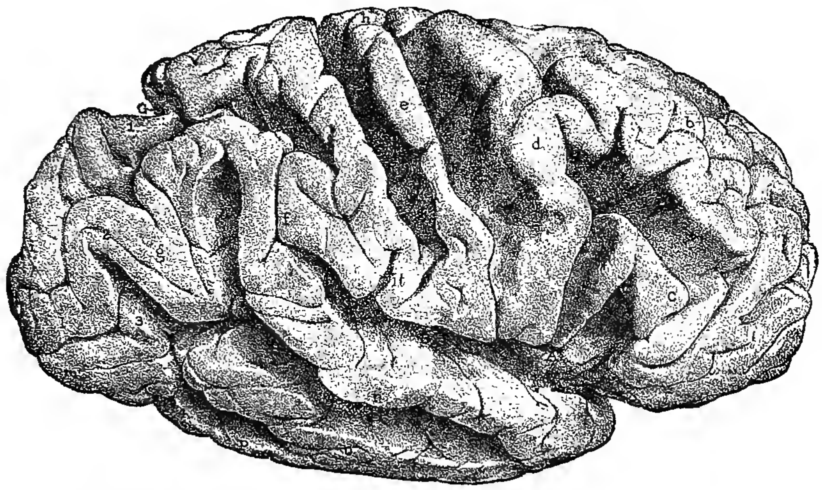


FIG. 41.—Right hemisphere of an adult male (reproduced from a photograph). It exhibits, in a well-marked form, the condition described as Variety III. of the intraparietal sulcus. The small oblique furrow in front of *i.t.* is the inferior transverse sulcus of the intraparietal (Eberstaller) partially united to the lower end of the sulcus postcentralis inferior.

A. . . Island of Reil.	*G.* . . External parieto-occipital fissure.
B. . . Posterior horizontal limb of the fissure of Sylvius.	*b* and *c*. . Second and third frontal convolutions.
C. . . Ascending limb of the fissure of Sylvius.	*d.* . . Ascending frontal convolution.
F. . . Fissure of Rolando.	*e.* and *h.* Ascending parietal convolution.

this long transverse furrow. It is uniformly deep throughout, and possesses a depth not far short of that of the fissure of Rolando. Its walls interlock through the presence of numerous secondary gyri, but there is no trace of a bridging convolution.*

* A condition of the intraparietal sulcus similar to this was described by Luys, " Description d'une circonvolution supplémentaire signalée dans certains cerveaux humaine, "Gaz. d. Hop.," Paris, 1876, xlix., p. 588.

It is not common, however, to find a specimen of this variety of the intraparietal sulcus so characteristic as that represented in figure 41. Nevertheless, of the 127 hemispheres examined, 17 came within the same class. In all of these there was a long continuous furrow placed behind the ascending parietal convolution, and parallel with the fissure of Rolando. As a rule, the upper part of this sulcus was shallower than the lower part, and in many cases it was partially cut off from it by a deeply-placed bridging gyrus, which crossed the bottom of the furrow and connected the posterior parietal lobule with the ascending parietal convolution. Further, the superficial bridge which intervened between the horizontal ramus of the fissure and the vertical part was not so strongly marked. In the atlas accompanying Gratiolet's *Mémoire sur les plis cérébraux de l'homme* this variety of the intraparietal sulcus is exhibited in a very complete form in the left hemisphere of the well-known "Hottentot Venus."

The following are the percentages for this variety of the intraparietal sulcus in the different groups of cerebral hemispheres examined:—

63 Adult hemispheres,	11·1 per cent.
8 Negro hemispheres,	25 ,,
19 Children's hemispheres,	5·2 ,,
17 Full-time fœtal hemispheres,	11·7 ,,
20 Eighth-month fœtal hemispheres,	25 ,,

Sernoff's results are again somewhat different from those which I have obtained.

Variety IV.—*The three parts of the sulcus confluent* (fig. 42).—This is by far the most usual condition of the intraparietal sulcus in the human brain. It was present in sixty-nine of the cerebral hemispheres examined.

63 Adult hemispheres,	60·3 per cent.
8 Negro hemispheres,	37·5 ,,
19 Children's hemispheres,	57·8 ,,
17 Full-time fœtal hemispheres,	41·3 ,,
20 Eighth-month fœtal hemispheres,	50 ,,

On the Continent it is usual to describe this variety of the intraparietal sulcus as the normal arrangement;* and in the numerous memoirs in which the cerebral hemispheres have been drawn from nature, it will generally be observed to be the condition depicted. It is interesting to note that the chimpanzee, gibbon, and in some cases the baboon and other apes, exhibit a similar disposition of the three rami of the intraparietal sulcus.

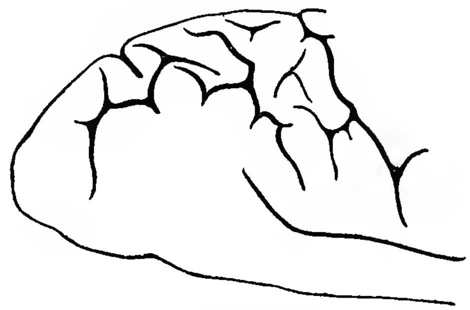


FIG. 42.—Posterior part of the left hemisphere of an elderly female. The more usual condition of the intraparietal sulcus is exhibited.

VARIETY V.—*Ramus horizontalis apparently joined to the lower end of the upper part of the postcentral sulcus; lower part of the postcentral sulcus separate* (fig. 43).—This is a very rare form of the intraparietal sulcus. It was noted in only two adult hemispheres and in one hemisphere from a child.

The condition in this variety of sulcus is easily explained if we bear in mind that it is not unusual for the sulcus postcentralis inferior to develop in two pieces which ultimately run into each other. In the abnormal arrangement under consideration the upper piece of this furrow has become confluent with the ramus horizontalis as usual, and also with the sulcus postcentralis superior, but it has failed to unite with the lower piece. The variety therefore can hardly be described as one in which the ramus horizontalis has become connected with the sulcus postcentralis superior, seeing that it only does so through the intermediation of the upper end of the

* For example, see Schwalbe's work on "Neurologie," p. 551, and Gegenbaur's "Text-book of Anatomy," p. 842, vol. ii., 3rd edition.

sulcus postcentralis inferior which, in this case, is developed as a separate element.

Now that we have considered the five different varieties of the intraparietal sulcus and noted the frequency of each at different periods of life,

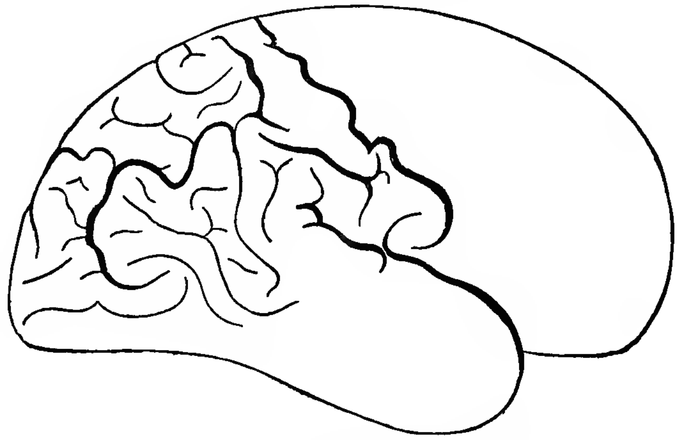


Fig. 43.—From Sernoff, and reproduced by the kind permission of the author. Illustrates Variety V. of the intraparietal sulcus.

there are certain deductions which may fairly be drawn from the facts detailed:—

1. In man there appears to be a general tendency towards a union of the two originally distinct postcentral elements of the sulcus and a divorce from the lower of these of the ramus horizontalis, which in its phylogenetic history is clearly continuous with, and in reality a part of it.

2. In the cerebral hemispheres taken from the fœtus and young child, we notice a greater number of cases in which one or more of the elements of the sulcus are separate and distinct from the remainder of the furrow than in the case of adults. This indicates that in certain cases union of these parts of the sulcus is delayed until the earlier part of childhood.

3. The discrepancies which exist between the percentages obtained by Sernoff for the Russian brain and those obtained by me for the Irish brain render it possible that in the arrangement of the different parts of the intraparietal sulcus we may ultimately be able to point out racial distinctions by a more extended study of this furrow-group.

4. That there are sexual differences in the arrangement of the different parts of the intraparietal sulcus is also possible, as may be noted from the following Table:—

	Variety I.	Variety II.	Variety III.	Variety IV.
37 Adult female hemispheres, .	3·1 p. c.	23 p. c.	6·2 p. c.	67·7 p. c.
32 ,, male ,, .	10·8 p. c.	16·2 p. c.	19 p. c.	54 p. c.

One or other, or perhaps both, of the postcentral sulci may establish connexions with the fissure of Rolando. The upper sulcus may run bodily across the ascending parietal convolution into the Rolandic fissure whilst the lower sulcus may be connected with it by a secondary branch. I have seen several cases of this kind, but it is not necessary to describe these

Fig. 44.—Posterior part of right hemisphere of a female 36 years old. It shows the sulcus postcentralis superior crossing the ascending parietal convolution and joining the fissure of Rolando.

separately or in detail. In some the superior postcentral sulcus alone was involved, and it joined the fissure of Rolando at a varying distance from the upper free margin of the hemisphere (fig. 44). In one case it was almost entirely absorbed in this way. In other instances not only did the upper postcentral sulcus run into the fissure of Rolando, but also the lower postcentral sulcus was joined to it by a cross-branch. In every instance the

junction was effected by a knuckling down of the ascending parietal convolution. When such connexions occur it appears to be common for the ascending frontal convolution to be divided in one or more places as well.

It is interesting to note that in a cerebral hemisphere obtained from a chacma baboon a superficial connexion was also observed between the ramus postcentralis superior and the fissure of Rolando.

V. **The Ramus Occipitalis of the Intraparietal Sulcus.**—This is unquestionably the most interesting part of the intraparietal system of furrows, and in the human brain its exact homology with the condition present in the apes is somewhat difficult to ascertain. In man it describes a U-shaped curve around the first annectant gyrus, and limits it externally. In front it is, as a rule, connected with the ramus horizontalis, whilst behind it ends in a short vertical furrow to which Ecker has applied the name of sulcus occipitalis transversus. A careful description of its course and relations is given by Schwalbe,* Ecker,† Gegenbaur,‡ Pansch,§ Eberstaller,‖ and other authors. The transverse occipital furrow is a shallow sulcus which runs transversely across a small extent of the outer surface of the occipital lobe a short distance behind the parieto-occipital fissure as it appears upon the superior border of the hemisphere. It is generally regarded as the representative of the "*Affenspalte*" in the apes, and therefore as a distinct and separate fissural integer. This conception of the sulcus transversus requires considerable modification.

The extremely concise description of Eberstaller may be regarded as embodying the general views which are held on this subject. He says:—"We proceed now to the consideration of the interparietal sulcus. This 'Furchen conglomerat' is disposed in three typical parts: an anterior transverse portion (sulcus postcentralis), a posterior transverse piece (sulcus transversus of Ecker), and a sagittal piece—the sulcus interparietalis in the

* Lehrbuch der Neurologie. Erlangen, 1881.

† Entwicklungsgeschichte der Furchen und Windungen, &c., &c., already referred to; and also his book, entitled Die Hirnwindungen des Menschen. Braunschweig, 1883.

‡ Lehrbuch der Anatomie des Menschen, Band 11. Vierte Auflage. Leipzig, 1890.

§ Die Furchen und Wülste. Berlin, 1879.

‖ Wiener Medizinische Blätter, 1884, No. 18, p. 547.

narrower sense. The sagittal furrow-segment pursues a backward course and describes an arch which is convex towards the mantle-border. The first half of this arch ascends slightly, the second descends more or less sharply. At the highest point of the arch the furrow sends a constant branch towards the mantle-border which bounds that convolution-loop which limits externally the parieto-occipital fissure. Immediately in front of this branch the sulcus is interrupted in typical cases, and here begins the descending portion of the furrow which bounds the arcus parieto-occipitalis laterally. This descending part . . . proceeds behind the parieto-occipital fissure, and opens without any intervening bridge into the hinder transverse segment. *This hinder transverse segment* (the sulcus transversus of Ecker) *is the analogue of the 'Affenspalte'; it is the fissura perpendicularis externa of the primate brain, and thus the boundary which limits the occipital lobe in front.*"

The descending portion of the sagittal segment of the furrow to which Eberstaller refers is the ramus occipitalis, and in many cases it is completely cut off from the ramus horizontalis (Eberstaller's ascending portion) by a superficial bridging gyrus. Indeed Wilder would seem desirous of placing it upon an independent footing altogether. He applies to it the special name of paroccipital fissure.* The grounds upon which he bases this view are briefly: (1) the separate development of this element; and (2) that "in the adult these two fissures (ramus occipitalis and ramus horizontalis) remain independent in about half of the cases, more often on the right side."

The separate development, however, of this element cannot be urged as a reason why we should place it outside the intraparietal system of furrows, because we might apply the same argument, with very nearly equal force, to all the other segments of this furrow-system. Further, although in its ontogeny it may appear as a distinct element, and even remain in this condition throughout life, its phylogeny shows in the clearest manner that it is a part of the intraparietal sulcus. The continuous intraparietal sulcus of the apes, presenting in itself all the elements which tend to break asunder from each other in man, affords us sufficient proof of this.

* "The paroccipital, a newly-recognized fissural integer."—Journal of Nervous and Mental Disease, vol. xiii., No. 6, 1886.

But again, in my examination of the adult human brain, I have not found the ramus occipitalis completely cut off from the ramus horizontalis in so large a percentage of cases as Professor Wilder. I have examined 133 hemispheres with the view of determining the relative frequency of this confluence of the ramus occipitalis and ramus horizontalis. The following are the results I obtained:—

Relative frequency of the Confluence of the Ramus Occipitalis with the Ra us Horizontalis.

Number of Hemispheres Examined and Period of Development.	The two Sulci Continuous.		The two Sulci separated by a Superficial Gyrus.	
	Actual Number of Hemispheres.	Percentage.	Actual Number of Hemispheres.	Percentage.
77 (adult), ...	49	63·7	28	36·3
16 (children from 3 mths. to 12 yrs.),	10	62·5	6	37·5
19 (full-time fœtuses), . . .	11	58·8	8	42·2
21 (eighth-month fœtuses), . .	7	33·3	14	66·7

From this Table it is evident that in many cases the union of the two fissural elements is delayed until after birth. In the adult, however, the confluence had not taken place at all in 36·3 per cent. of the hemispheres examined.

I can confirm in every particular a statement which has been made both by Ecker and Wilder, viz. that the union of the ramus occipitalis and the ramus horizontalis of the intraparietal sulcus takes place more frequently on the left side than on the right side. In 28 hemispheres which I studied in connexion with this question I was much surprised to find a union of the two elements in 87·5 per cent. of the left hemispheres, and in only 58·4 of the right hemispheres.

VI. **The Sulcus Occipitalis Transversus of Ecker.**—The question we have now to decide is whether the sulcus occipitalis transversus is to be

regarded as an independent fissure or as a dependency of the ramus occipitalis of the intraparietal sulcus. Upon phylogenetic as well as upon ontogenetic grounds, I have been led to believe that the furrow in question cannot be regarded as being in man the homologue of the "Affenspalte" in the apes; nor can it be looked upon as constituting an entirely independent fissural element. It belongs in part, if not in whole, to the intraparietal fissure-system, and is simply the hinder bifurcation of the ramus occipitalis. In support of this contention we shall, in the first instance, bring forward some facts in connexion with the condition present in the apes, and then study its mode of development in the fœtal human brain.

Let us begin with the simple arrangement which is present in the brain of *Cebus capucinus*. The intraparietal sulcus ascends obliquely in an upward and backward direction, and approaches the upper margin of the hemisphere where the parieto-occipital fissure makes its appearance on the outer surface. Here it bends upon itself and turns sharply downwards for a short distance behind the summit of the angular gyrus, and under cover of the occipital operculum. The parieto-occipital fissure, as it cuts through the upper hemisphere border, opens freely into the angle of bending. This is seen in figure 45, p. 222. In the left hemisphere of the cerebrum represented, the operculum has been removed, so that the entire fissural arrangement is exposed; in the right hemisphere, where the operculum is in place, the bottom of the "Affenspalte," as well as the short descending part of the intraparietal sulcus are represented by dotted lines. Three parts, then, are here recognisable, viz. a long ascending limb, a short descending limb, and the parieto-occipital fissure, as it appears on the outer surface, and all the three are directly and uninterruptedly continuous. The descending limb represents a part, but not the whole, of the ramus occipitalis of the intraparietal system of sulci in man, and it should be noticed that in *Cebus capucinus* it does not reach the bottom of the "Affenspalte," although it usually lies under cover of the operculum.

In the five cerebral hemispheres of this species of new-world apes which I have in my possession, I notice that there is a considerable difference in different individuals in the degree of development or forward projection of the operculum. In one specimen, indeed, it is so short that the entire

length of the descending limb of the intraparietal sulcus lies exposed on the surface of the cerebrum in front of the opercular lip.

In dealing with this region of the simian brain I have avoided using the term "external parieto-occipital fissure," because it has been employed in this country in so many different senses. Thus it has been used to denote:

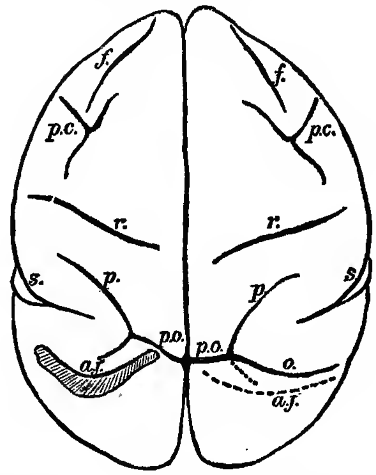


FIG. 45.—Cerebrum of *Cebus capucinus* viewed from above. Drawn by the American apparatus for tracing orthogonal projections of the skull. The hinder end of the cerebrum is tilted upwards, in order that the occipital part may be brought more fully into view. On the left side the occipital operculum has been removed, so that the descending hinder part of the intraparietal sulcus may be displayed. The cut surface of the operculum is represented by shading. On the right side the operculum is in place, and the bottom of the "Affenspalte" and the hinder end of the intraparietal sulcus, under cover of it, are represented by dotted lines.

f.	Sulcus frontalis inferior.	*p.*	Intraparietal sulcus.
p.c.	Sulcus præcentralis inferior.	*p.o.*	Parieto-occipital fissure.
r.	Fissure of Rolando.	*o.*	Anterior lip of the occipital operculum.
s.	Fissure of Sylvius.	*a.f.*	Bottom of the "Affenspalte."

(1) the incision which is made in the upper margin of the hemisphere by the internal parieto-occipital fissure, and this is the only sense in which it should be used; (2) the superficial furrow which, when the operculum is in position, runs along the anterior lip of this structure, and at first sight appears to be continuous with the true parieto-occipital fissure on the inner surface of the hemisphere; and (3) the bottom of the pocket or recess enclosed by the operculum. Owing to the different degrees of development

of the operculum, the bottom of the underlying recess is the only fixed part of this slit-like fissure. This is placed at some distance behind the parieto-occipital fissure as it cuts the upper border of the hemisphere (*v.* fig. 45), and to avoid confusion I have applied to it the German term of "Affenspalte."

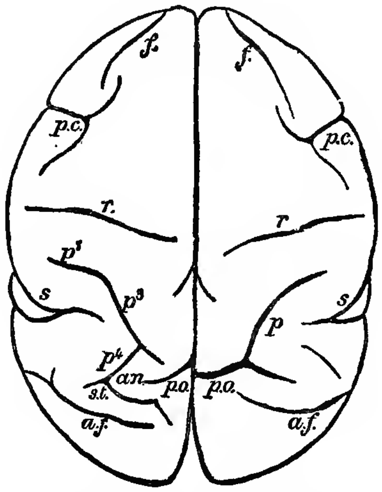


Fig. 46.—Cerebrum of *Cebus albifrons* as seen from above. Drawn by the American apparatus for tracing orthogonal projections of the skull. The hinder end of the cerebrum was tilted slightly upward, in order that the occipital region might be brought more fully into view.

f. . . Sulcus frontalis inferior.
p.e. . . Sulcus præcentralis inferior.
r. . . Fissure of Rolando.
s. . . Sylvian fissure.
p. . . Intraparietal sulcus.
*p.*¹ . . Sulcus postcentralis inferior.
*p.*³ . . Ramus horizontalis.
*p.*⁴ . . Ramus occipitalis.
s.t. . . Corresponding furrow to the sulcus transversus occipitalis of Ecker.
p.o. . . Parieto-occipital fissure.
a.n. . . First annectant gyrus (arcus parieto-occipitalis.
a.f. . . "Affenspalte."

Pansch has aptly compared the occipital operculum of the apes to the fronto-parietal operculum which covers the island of Reil. In this case we may compare the bottom of the opercular recess, or "Affenspalte," to the furrow which bounds the island of Reil above, and the superficial furrow along the anterior edge of the occipital operculum with the posterior limb of the Sylvian fissure.

But an operculum is not universally present in the apes. In four hemispheres obtained from *Cebus albifrons* I find that the operculum is

either extremely feeble or entirely absent. The "Affenspalte," therefore, is seen even on superficial inspection to lie well behind the parieto-occipital fissure, whilst the whole length of the intraparietal sulcus is exposed on the surface (fig. 46, p. 223). Further, the connexion of the intraparietal sulcus and parieto-occipital fissure is very evident. In some cases this confluence is perfectly free and unbroken; in other instances it is partially interrupted by a low-lying feeble, deep annectant gyrus. In one hemisphere, which I shall have to take special notice of later on, this deep gyrus has risen to the surface, and presents an appearance very similar to the condition present in man (fig. 46, left hemisphere).

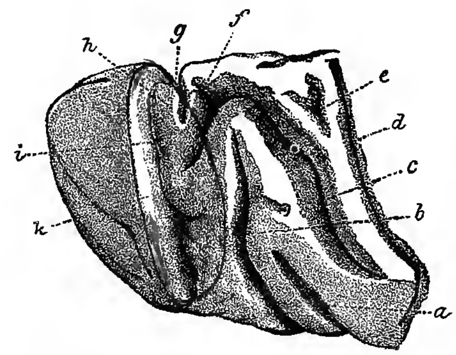


Fig. 47.—Posterior part of the right cerebral hemisphere of the Chacma baboon looked at from above. The occipital operculum has been removed.

a. . . Sylvian fissure.
b. . . Parallel sulcus.
c. . . Intraparietal sulcus.
d. . . Fissure of Rolando.
e. . . Sulcus postcentralis superior.
f. . . Branch from intraparietal sulcus in front of the first annectant gyrus.
g. . . The upper end of the internal perpendicular fissure.
h. . . First annectant gyrus.
i. . . "Affenspalte."
k. . . Cut surface of the occipital operculum.

In carrying out our comparison between the intraparietal sulcus in man and the corresponding sulcus in the apes, it is very evident, therefore, that where an operculum exists in the latter, it is necessary, in the first instance, to remove this structure, or at least to throw it well backwards.

The baboon will serve for our next stage (fig. 47). In the brain of this form there is a deeply placed annectant gyrus (*h.*) (the first bridging convolution) which partially cuts off the parieto-occipital fissure (*g.*) from the

intraparietal sulcus (*c.*). This gyrus is sharply defined in front by a branch of the intraparietal sulcus which extends upwards in front of it (*f.*). Posteriorly it is limited by a furrow which corresponds with the upper part of the bottom of the opercular slit (*i.*), whilst externally it is limited by the short descending limb of the intraparietal fissure. The latter, however, as in Cebus, has no connexion with the bottom of the recess formed by the operculum.

Fourteen hemispheres obtained from Cynocephalus presented characters which closely correspond with those represented in figure 47. Considerable differences were noted in the degree of development of the first annectant gyrus (*h.*). In all it was thrust deeply down below the surface, but in some of the specimens (as, for example, the one which is figured above), it was much more conspicuous than in the others.

In ten hemispheres taken from the macaque the condition present was closely similar to that which we have described as existing in the baboon.

An arrangement of the fissure, which is frequently present in the chimpanzee (fig. 48, p. 226), leads us directly up to man. The first annectant gyrus is still partially hidden from view, but it has risen much nearer to the surface (*h.*). It constitutes a distinct barrier to the communication between the parieto-occipital fissure as it turns outwards on the hemisphere and the intraparietal fissure. On removal of the operculum the descending short limb of the intraparietal sulcus is seen to bound the first annectant gyrus externally, and then bifurcate. The upper limb runs directly upwards, and joining the bottom of the "Affenspalte," limits the first annectant gyrus posteriorly (*k.*) whilst the lower limb turns downwards under cover of the operculum, but is soon called to a halt, because the deep and hidden second annectant gyrus interposes itself in the way. The upper terminal limb is a new branch. We have seen in the baboon how a branch is sent up from the intraparietal sulcus in front of the first annectant gyrus; here in the chimpanzee there is a branch which is sent up behind it, but this soon loses itself in the bottom of the "Affenspalte." The lower terminal branch of the bifurcation is simply the down-turned end of the intraparietal sulcus as we have seen it in Cebus and the baboon.

The arrangement of the sulcus in the chimpanzee hemisphere represented below is so suggestive and instructive that I have given another view of it, as seen from above, in figure 35, p. 103. This drawing was made by means of the American apparatus for tracing orthogonal projections of the skull, and it will be noticed that the upper limb of the terminal bifurcation of the intraparietal sulcus (*b*) is not completely absorbed by the bottom of

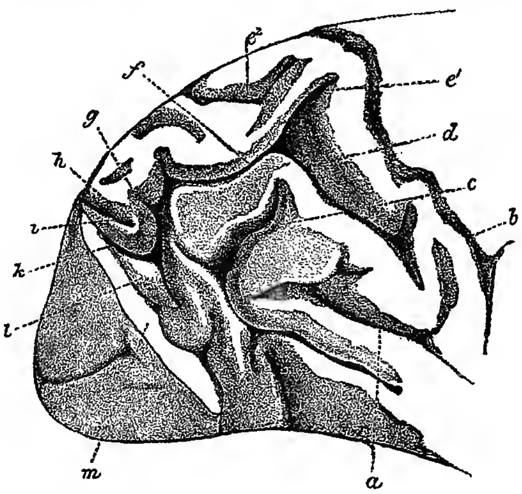


FIG. 48.—Posterior portion of the right hemisphere of a young female chimpanzee.

a. . . Fissure of Sylvius.
b. . . Fissure of Rolando.
c. . . Parallel sulcus.
d. . . Ramus verticalis inferior of the intraparietal sulcus.
e. . . Ramus verticalis superior of the intraparietal sulcus.
f. . . Ramus horizontalis of the intraparietal sulcus.
g. . . The branch which limits the first annectant gyrus in front.
h. . . The first annectant gyrus.
i. . . The internal perpendicular fissure as it turns out on the upper surface of the hemisphere (external parieto-occipital).
k. . . The branch of the intraparietal sulcus which turns up behind the first annectant gyrus to join the "Affenspalte."
l. . . Second annectant gyrus.
m. . . Cut surface of the occipital operculum.

the "Affenspalte." At its upper end it again asserts its independence. In the left hemisphere we see the same terminal bifurcation of the intraparietal sulcus, but the lower limb of this is extremely feeble, and might escape notice were we not already acquainted with the condition present on the right side. In figure 36, p. 204, a view of the upper surface of the

cerebrum of another chimpanzee is given. On the left side the terminal bifurcation of the intraparietal sulcus is exhibited, although it will be seen that the lower limb is very weakly developed; on the right side, however, the intraparietal sulcus runs bodily into the bottom of the "Affenspalte."

I think we may fairly take the condition present in the chimpanzee hemisphere figured in p. 226, as being the typical arrangement in this animal, seeing that in two of the other three chimpanzee hemispheres examined it was also present, although not in so marked a manner. Such being the case if we now suppose the operculum abolished, and the two annectant gyri in relation to the hinder end of the intraparietal sulcus raised to the surface, we have the condition present in man. The terminal bifurcation of the intraparietal sulcus, with its widely spread out limbs, constitutes the sulcus transversus. Instead of being completely or partially concealed, as in the lower forms, it is in man exposed to view on the surface.

It is somewhat curious that we should obtain confirmatory evidence of the accuracy of these views in an aberrant arrangement of the intraparietal sulcus which was present in one of the specimens obtained from *Cebus albifrons*. The cerebrum in question is figured in page 223. The left hemisphere shows a condition closely corresponding to that observed in man. Here the operculum is absent although the "Affenspalte" (*a. f.*) exists in the shape of a curved fissure placed a short distance behind the parieto-occipital fissure. In this particular hemisphere the first annectant gyrus, which in this species of ape is, as a rule, either absent or very feeble and deeply placed (*vide* right hemisphere of same brain), is raised completely to the surface (*a.n.*), and completely shuts off the parieto-occipital fissure from the intraparietal sulcus. The ramus occipitalis of the intraparietal sulcus is clearly marked out. It surrounds the first annectant gyrus externally, and ends in a terminal bifurcation, the diverging limbs of which form a sulcus occipitalis transversus (*s. t.*) in every respect similar to the fissure of the same name in the human brain.

At this stage I am induced to bring forward the cerebrum of a newly-born child in which there is a fissure which is undoubtedly the representative of the "Affenspalte" (fig. 49, p. 228). In front of this is seen the terminal bifurcation of the occipital part of the intraparietal sulcus forming the

sulcus transversus occipitalis of Ecker. The whole arrangement is very similar to what we have seen in the chimpanzee and the aberrant hemisphere of *Cebus albifrons.* I have already referred to this cerebral hemisphere (p. 68), so I need not enter into the condition it presents in further detail. I may mention, however, that I have seen the same condition present on one or two occasions in the adult human brain. I am therefore very far from denying that the "Affenspalte" is invariably absent in man. I only contend that it is not identical with the sulcus transversus of Ecker.

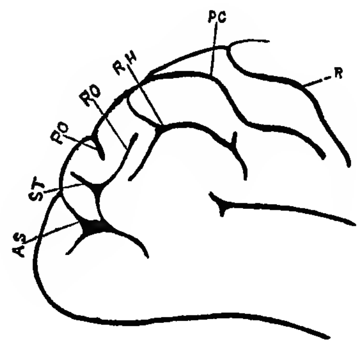


Fig. 49.—Right hemisphere of new-born child. R., fissure of Rolando; P.C., postcentral sulcus; R.H., ramus horizontalis of the intraparietsl fissure; R.O., ramus occipitalis; S.T., sulcus transversus occipitalis of Ecker; A.S., "Affenspalte"; P.O., parieto-occipital fissure.

As we have noted, the occipital part of the intraparietal sulcus in the human brain is either continuous with the main part of the fissure, or else it has a separate origin in the superior parietal lobule. As it passes backwards it sends a branch in front of the first annectant gyrus, and in its typical condition divides in the occipital lobe beyond that gyrus into two terminal branches. These are so widely spread out that they deviate from each other very nearly in the same straight line, and constitute the sulcus transversus. The lower limb of the bifurcation owes its origin undoubtedly to the intraparietal sulcus; it corresponds to the lower part of the short descending limb in the apes which is brought into view when the operculum is removed. The upper limb bounds the first annectant gyrus posteriorly, and it is more difficult to decide upon its nature. In the baboon the first annectant gyrus is bounded behind by the upper part of

the "Affenspalte" alone, whilst in the chimpanzee a branch is generally given off from the intraparietal, which turns up and joins this part of the "Affenspalte," giving rise to the appearance of a terminal bifurcation of the intraparietal sulcus. It would appear, therefore, that if the sulcus transversus has any relation to the "Affenspalte" it is only in its upper part.

The chief evidence, and I might almost say the only phylogenetic evidence, of the view which is generally entertained regarding the identity of the sulcus transversus occipitalis of Ecker and the "Affenspalte" is obtained from such forms as the white-crowned mangaby (*Cercocebus aethiops*) (fig. 50). In the brain of this ape, and indeed in many others, the intraparietal sulcus sends up the usual branch in front of the first annectant gyrus. It then runs round its outer aspect, and, approaching the bottom of the recess under the operculum, bifurcates into two branches which, in diverging from each other, lose their identity in the bottom of the "Affenspalte." The same condition may be seen in the orang-utan (fig. 37, p. 206), and also occasionally in the chimpanzee (fig. 36, p. 204, right hemisphere).

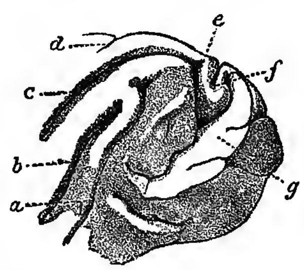


Fig. 50.—The posterior part of the left hemisphere of the white crowned mangaby. *a*, parallel sulcus; *b*, fissure of Sylvius; *c*, intraparietal sulcus; *d*, sulcus postcentralis superior; *e*, descending limb of the intraparietal sulcus; *f*, upper end of parieto-occipital fissure turning outwards on the upper surface of the hemisphere; *g*, cut surface of occipital operculum.

Taken by itself this condition in these apes might be regarded as affording presumptive evidence in favour of some kind of connexion between the sulcus transversus occipitalis and the "Affenspalte"; but in the face of the other facts brought forward it proves very little.

I have tried to show that the phylogenetic evolution of the sulcus transversus would seem to indicate that it is not an independent sulcus, but

one which belongs to the same system as the intraparietal. The onto-genetic development of the sulcus furnishes evidence of a still more satisfactory nature.

In a previous chapter (Chapter I., pp. 67–69) we have seen: 1, that there is little room for doubt that the fissura perpendicularis externa of Bischoff is the representative of the "Affenspalte" in the apes; 2, that this is a complete fissure, and produces a distinct bulging into the interior of the posterior horn of the lateral ventricle; 3, that it is evanescent, and in almost every case disappears before the sulcus transversus occipitalis shows on the surface of the hemisphere; 4, that the "Affenspalte" of the apes is a complete fissure, whilst the sulcus transversus occipitalis is not. These facts of themselves are sufficient to show that there are very great difficulties in the way of regarding these two fissures as homologous with each other. But a study of the manner in which the terminal bifurcation of the ramus occipitalis developes places the matter beyond a doubt. This is well seen in figure 33, Plate I. The bifurcation (*i. e.* the sulcus transversus) first makes its appearance towards the close of the seventh month or the beginning of the eighth month.

In the specimen referred to (fig. 33, Plate I.), the lower limb of the bifurcation is formed by a downward inclination of the terminal part of the main stem of the ramus occipitalis, whilst the upper limb is present in the form of a shallow depression behind the arcus parieto-occipitalis (first annectant gyrus) which runs into the ramus occipitalis a short distance from its extremity. Sometimes this upper limb remains separate for a considerable time, and even when it joins the ramus occipitalis the point of junction may be marked by a deep annectant gyrus. In twenty-eight adult hemispheres I noticed such an annectant in three specimens.

But the terminal bifurcation of the ramus occipitalis is extremely variable in its mode of development, and that exhibited in figure 33, Plate I., cannot be considered as being the typical or more usual mode. In its early condition the ramus occipitalis commonly describes a U-shaped curve around the arcus parieto-occipitalis (first annectant gyrus), and in many instances the hinder limb of the U forms the upper limb of the later terminal bifurcation (sulcus transversus), whilst the lower limb is a new

offshoot. This is seen in the left hemisphere of the fœtal brain figured in page 232 (fig. 51).

I have already alluded to the fact that in cases where the upper end of the parieto-occipital fissure on the inner face of the hemisphere bifurcates, and its two terminal branches appear on the outer surface of the hemisphere, there is a tendency for the ramus occipitalis to develope in the form of two sulci—one in relation to the upper end of each branch of the divided parieto-occipital fissure. Usually these two pieces of the ramus occipitalis run rapidly into each other, but in one specimen in my possession (a hemisphere taken from a fœtus well on in the eighth month), they are still quite distinct, and further the posterior extremity in each *ends in a terminal bifurcation or sulcus transversus.*

All these facts in connexion with the development of the sulcus transversus occipitalis of Ecker are directly opposed to the view that it is an independent fissural element, distinct from the intraparietal sulcus, and the representative in man of the "Affenspalte." Still, it must be admitted that in rare cases it is developed in the form of a continuous transverse furrow which is, in the first instance, separate from the ramus occipitalis. Ecker figures the brain of an eighth-month fœtus in which this is the case, and, no doubt, this specimen greatly influenced him in the views he has expressed in regard to its nature. In my collection of fœtal brains I have a very beautiful specimen of the same kind, and I consider it so important that I have had it figured (fig. 51, p. 232). The condition is only present in the right hemisphere. The ramus occipitalis is seen to consist of three parts, viz. an anterior vertical portion, an intermediate sagittal piece, and a hinder vertical part. It is the last of these which is the representative of the sulcus transversus. This specimen, no doubt, introduces an element of difficulty into the question, but it does not shake me in my belief that the sulcus transversus has nothing to do with the "Affenspalte," because we see in front of the ramus occipitalis in this specimen an independent transverse element of a precisely similar character, and it appears to me that we are merely dealing with a case in which the usual U-shaped furrow has become broken up into three segments.

This aberrant mode of development of the ramus occipitalis explains

the presence of a deep annectant gyrus which is occasionally seen crossing the bottom of the ramus occipitalis at its junction with the sulcus transversus occipitalis. In twenty-eight adult hemispheres I have seen this deep

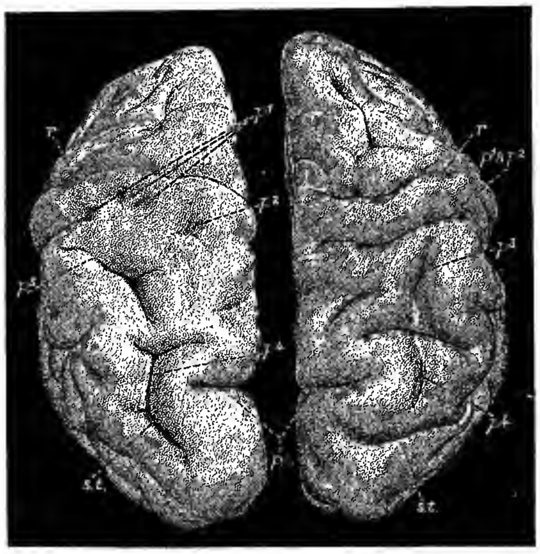


FIG. 51.—The two cerebral hemispheres of a fœtus (seven and a-half months) viewed from above. The figure is reproduced from a photograph. The left hemisphere is remarkable on account of the number of separate depressions which together represent the postcentral sulcus.

r. . . Fissure of Rolando.
$p.^1$ . . Sulcus postcentralis inferior.
$p.^2$ . . Sulcus postcentralis superior.
$p.^3$ . . Ramus horizontalis.
$p.^4$ . . Ramus occipitalis.
s.t. . . Sulcus occipitalis transversus of Ecker.
p.o. . . Parieto-occipital fissure.

gyrus in three specimens; in the full-time fœtal brain, however, I have met with it more frequently.*

* It appears to me that the sulcus occipitalis transversus presents very much the same relations to the ramus occipitalis that the fronto-marginal sulcus of Wernicke exhibits to the sulcus frontalis medius. Both of these transverse furrows form the terminal bifurcations of the sagittal sulci with which they stand in connexion; and further, as we shall see later on, the fronto-marginal furrow may be developed in three ways, which correspond exactly with the three modes of development described for the sulcus transversus occipitalis: (1) as an independent furrow; (2) its mesial limb may be developed separately, whilst its lateral limb is developed in direct continuity with the sulcus frontalis medius; (3) the lateral limb may show an independent development, whilst its mesial limb is formed in direct continuity with the sulcus frontalis medius.

Of the more recent workers at the surface anatomy of the human cerebrum there is no one who has shown a keener insight into the conditions present, or a more judicious appreciation of the homologies which exist between the convolutions and sulci in man and those in the apes, than Eberstaller of Graz.* We have already noted that he does not claim that the sulcus transversus of Ecker is the homologue of the "Affenspalte" in the apes—merely, the "analogue." What he exactly means by this I am unable to understand, more especially as he applies the term "Affenspalte" to the sulcus transversus in the human brain. Further, he appears to draw a distinction between the upper and lower limbs of the sulcus occipitalis transversus of Ecker. Thus he remarks: "In it we can distinguish a medial and a lateral segment by the point of junction with the sagittal portion of the interparietal furrow; the former bounds the arcus parieto-occipitalis (the first annectant gyrus) behind, without, in the majority of cases, reaching the mesial border, the latter is the sharply descending end of the arch-like fissura interparietalis."† In the abstract which I published in the Journal of Anatomy and Physiology of this chapter (Vol. XXIV.), and which was written before I had become acquainted with all the work which Eberstaller has done in this field, I expressed myself in somewhat similar terms. I contended that the lower part of the sulcus transversus was the representative of the down-turned extremity of the ramus occipitalis of the intraparietal sulcus, and that it was possible that the upper part had some connexion with the "Affenspalte." As will be seen from what goes before, a more extended study of the question, and a great addition to the number of my specimens, have led me to believe that the entire sulcus occipitalis transversus of Ecker is quite independent of the "Affenspalte" of the apes, and has, in point of fact, nothing to do with it whatever.

Eberstaller very rightly disputes Ecker's assertion that the posterior lip of the sulcus transversus occipitalis in the human brain projects forwards in some cases so as to overlap the anterior lip in the form of an operculum. He says: "I have examined the 'Affenspalte' ‡ in from two to three

* Wiener Medizinische Blätter, No. 19, 1884, p. 582.

† Wiener Medizinische Blätter, No. 18, 1884, p. 548.

‡ By this he refers to the sulcus occipitalis transversus of Ecker.

hundred hemispheres, but have never recognised such a projection of its posterior border; quite the opposite: in most cases it is the anterior border which shows an operculum-like projection; therefore the whole hinder half of the interparietal furrow penetrates the cerebral surface obliquely, so that the hinder part of the inferior parietal lobule overlaps the hinder part of the upper parietal lobule and the fore-border of the occipital lobe. Stark makes an analogous observation, and this agrees entirely with the higher development of the human brain. The parietal and occipital lobes contend with each other for surface-extension; in the lower apes the latter bulges over the former: it remains the victor and reaches forwards as far as the first annectant gyrus. Already in the orang-utan the occipital operculum has suffered a great reduction; but in man the victory is on the side of the parietal lobe; it presses the other (the occipital lobe) back and begins on its part to overlap it." I fully agree with these suggestive remarks of Eberstaller, and can corroborate his statements regarding the preponderance of the inferior parietal lobule in the cerebrum of man.

It is hardly necessary to allude to the views which have been put forward by Wernicke* in regard to the "Affenspalte." He describes a transversely directed furrow on the outer surface of the human brain, and in a line with the parieto-occipital fissure. This he terms the "vordere Occipitalfurche," and he holds that it is the representative of the "Affenspalte" in the apes. Eberstaller has conclusively shown that the furrow in question is merely the vertical terminal bifurcation of the second temporal furrow. It stands in relation to this furrow in the same manner as the corresponding terminal bifurcations do to the parallel and Sylvian fissures, and also, we might add, as the sulcus transversus occipitalis of Ecker does to the ramus occipitalis of the intraparietal sulcus.

VIII. **Deep Annectant Gyri in the Intraparietal Sulcus.**—Eberstaller has given so satisfactory a description of the deep gyri which bridge across the bottom of the intraparietal sulcus in the adult human brain that it is not necessary to enter into this aspect of the question in any detail. In the

* "Das Urwindungssystem des menschlichen Gehirns.—Archiv für Psychiatrie und Nervenkrankheiten," Band vi., Heft i., 1875.

course of the postcentral sulcus three deep gyri may be present. The highest of these marks the point of junction between the sulcus postcentralis superior and the sulcus postcentralis inferior. In many cases the union between these two elements of the fissure is so complete that not a trace of this deep annectant gyrus can be detected. The second deep gyrus within the postcentral sulcus marks the point of union between the inferior transverse sulcus of Eberstaller and the main stem in those cases in which these are found confluent. The third deep annectant gyrus is only present in very exceptional cases. It intercepts the continuity of the sulcus postcentralis inferior, and shows, even in the adult brain, that this portion of the fissure may be developed out of two pieces (*vide* fig. 51, p. 232). As we have seen, in our study of the adult condition of this fissure, the superior annectant gyrus remains on the surface in about every fourth hemisphere (25·4 per cent.). The inferior annectant gyrus is in the great majority of cases on the surface. The presence of the middle annectant as a superficial gyrus is an exceedingly rare occurrence.

In those instances in which the ramus horizontalis is confluent with the postcentral sulcus, the presence of a deep gyrus, partially interrupting the union, is a very common occurrence. It is termed, by Eberstaller, "the anterior deep annectant gyrus"; further, when the ramus occipitalis runs into the ramus horizontalis, the point of union is almost invariably indicated by a deep gyrus, viz. the "posterior deep annectant gyrus" of Eberstaller. These are the deep gyri which are present in the sagittal part of the furrow in typical cases, but additional deep bridging convolutions are occasionally met with: viz. (1) in the course of the ramus horizontalis; (2) in the course of the ramus occipitalis; (3) at the junction of the ramus occipitalis and the sulcus transversus occipitalis of Ecker; and (4) at the point where the superior limb of the sulcus transversus of Ecker joins the inferior limb. Of these occasional deep annectant gyri, the two latter have already been referred to, and their presence explained (pp. 230 and 232). The deep interrupting gyri in the course of the ramus horizontalis and ramus occipitalis simply indicate that these segments of the sulcus may each be developed out of two pieces which, in the course of time, run into each other.

Wernicke,* in discussing the significance of these intraparietal deep gyri, has come to the conclusion that they are peculiar to the human brain, and to this statement Mihalkovics† adds the following remarks:—"The more strongly expressed, and the more superficial these interparietal bridges are, the more highly developed is the brain, and *vice versa.* In the apes the interparietal furrow is not bridged over." The latter part of this assertion has also been repeated by Rudinger,‡ who says: "In no primate brain does the sagittal portion of the interparietal furrow become bridged over." This is not correct, however, because deep annectant gyri may be found in the course of the intraparietal sulcus of the chimpanzee. In two hemi spheres, taken from the same animal (fig. 36, p. 104), a strongly-marked bridge interrupted the junction between the ramus horizontalis and the postcentral sulcus, whilst in two other hemispheres (fig. 35, p. 103) a very distinct deep gyrus indicated the point of union between the ramus occipitalis and the ramus horizontalis. Further, in the baboon it is by no means infrequent to find a deep annectant gyrus at the latter point.

VIII. **The Intraparietal Angle.**—Under this heading I purpose dealing with the inclination of the sagittal part of the intraparietal sulcus (*i. e.* the combined horizontal and occipital rami), and establishing the angle at which its hinder end, when produced, intersects another line corresponding to the mesial plane prolonged backwards. This leads us to consider the work which Rudinger has done in the same direction. This author has endeavoured to prove that the inclination of the sagittal portion of the sulcus differs according to sex, race, and the intellectual capacity of the individual, and that we can recognize by this feature a regular gradation from the low apes up through the anthropoid apes, the human female, the human male, until we finally arrive at those individuals possessed of exceptional mental endowments. He says: "No furrow and no convolution influences the position

* "Das Urwindungssystem des menschlichen Gehirns," Archiv für Psychiatrie," Band vi.

† Entwicklungsgeschichte des Gehirns, Leipzig, 1877, p. 154.

‡ "Ein Beitrag zur Anatomie der Affenspalte und der Interparietalfurche beim Menschen nach Race, Geschlecht und Individualität."—Beiträge zur Anatomie und Embryologie als Festgabe, Jacob Henle, von seinen Schülern, Bonn, 1882.

of the interparietal furrow more than the first external annectant gyrus of Gratiolet—that arched convolution which bounds the perpendicular fissure towards the parietal region. Already the gradual increase in the development of this convolution as we pass from the lower apes up to the primates and its progressive transformation to a primary convolution, justify the conjecture that it attains a special importance in the higher animals, and also in man. For this annectant gyrus shows a greater difference, according to sex, race, and individuality, than any other region of the brain-cortex. In the female it is usually present in the form of a simple smooth arch which surrounds the perpendicular fissure. Already, for some years had I learnt to recognise this fact, and also the necessary consequence that one could determine the sex by the form and arrangement of this arching convolution, and the depth of the parieto-occipital fissure. The shortness and the simplicity of the curve of this arching gyrus is associated with a smaller depth of the perpendicular fissure, and these peculiarities are very characteristic of the hemispheres of the female brain. In cases where this convolution occupies a small amount of space on the hemisphere, the 'Affenspalte' and the hinder end of the sagittal limb of the interparietal sulcus become only slightly turned lateralwards, and it therefore follows that the latter furrow assumes an oblique direction. . . . In the female brain the entire extent of the superior parietal lobule, and the first annectant gyrus, remain distinctly backward in their degree of development, and these two factors together are the cause of the described characteristic direction of the interparietal furrow. . . . Especially characteristic of the male parietal lobe is the altered direction of the interparietal sulcus, which assumes a more sagittal direction."*

I regret that I cannot confirm these observations of Rudinger. I have found—(1) that the *relative* size of the arcus parieto-occipitalis (first annectant gyrus) is not appreciably different in the male and the female; (2) that it is relatively more bulky in the anthropoid apes than in man; (3) that the obliquity of the sagittal portion of the intraparietal sulcus is apparently more marked in the male than in the female; (4) that it is in

* "Ein Beitrag zur Anatomie der Affenspalte und der Interparietalfurche beim Menschen nach Race, Geschlecht und Individualität." Henle's Festschrift, Bonn, 1882, pp. 194 and 195.

the anthropoid apes that the sagittal portion of the intraparietal furrow assumes the most distinctly sagittal direction; (5) and, finally, I agree with Eberstaller in considering that it is the inferior parietal lobule which shows a relative increase in size in the evolution of the parietal lobe, and not the superior parietal lobule. It is necessary, however, that I should bring forward the evidence upon which these assertions are based.

Relative size of the arcus parieto-occipitalis.—I have measured this gyrus, from the mesial plane to the highest point of its convexity, in twenty-eight adult human hemispheres, in twenty-three human fœtal hemispheres, varying in development from the eighth month up to the full period, and in eight anthropoid hemispheres. The results I obtained are contained in the following Table:—

RELATIVE SIZE OF THE ARCUS PARIETO-OCCIPITALIS.

Mesial Length of the Cerebrum being reckoned as 100.

	MALE.		FEMALE.	
	Number of Hemi-spheres.	Index.	Number of Hemi-spheres.	Index.
Adult human brain,	15	11	13	11·2
Fœtal human brain (from eighth month to full-time),	9	9·3	14	10·6
Chimpanzee brain,	—	—	4	16·2
Orang-utan brain,	4	16·9	—	—

In the adult human brain there is, therefore, virtually no sexual difference to be detected in the relative size of the arcus parieto-occipitalis. In the fœtal brains, however, we note that in the female the relative size of this gyrus is greater (index 10·6) than it is in the male (index 9·3). But the most striking point brought out by this Table is the great relative size of the gyrus in the chimpanzee and the orang. Eberstaller has, in a measure,

observed the same peculiarity in the anthropoid brain. Thus he remarks:—"Meine Studien führten mich dahin, dass ein Weitnachaussenragen der parieto-occipital-Spalte mit dem sie umrandenden Windungsbogen eine Eigenthümlichkeit des Anthropoïden-Gehirnes, also inferiorer Entwicklung sei, während gerade im Gegentheile eine starke Entwicklung des unteren Scheitellappens ein Signum höherer Entwicklung abgebe."

Inclination of the sagittal part of the Intraparietal sulcus.—The inclination of the sagittal part of the intraparietal sulcus does not entirely depend upon the degree of development of the first annectant gyrus. This of course affects the position of its hinder end; but its anterior end at its point of junction with the postcentral sulcus is also liable to changes of level, and these likewise influence the inclination of the furrow.

The inclination of the furrow can best be appreciated by measuring the angle which is formed by the intersection of two lines drawn backwards which correspond respectively to the mesial plane and to the sagittal part of the sulcus. This angle may be termed the "intraparietal angle." I have determined it in a number of brains by means of the American apparatus for tracing orthogonal projections of the skull. My plan of operation has been the following: One pin was introduced into the hemisphere at the junction of the sagittal portion of the intraparietal sulcus with the postcentral furrow, and another pin into the hinder end of the sulcus at its point of bifurcation into the sulcus transversus. A line drawn between the two pin-heads was considered to give the direction of the sulcus. A number of parallel straight lines were then drawn upon the varnished plate of glass of the instrument, and the hemisphere was adjusted below this, so that whilst one of these lines corresponded with the mesial plane of the brain another passed through the hinder pin-head or posterior end of the sulcus. By means of the periglyph the accuracy of this adjustment could easily be tested, and the position of the hinder pin-head on the straight line which passed through it indicated. The position of the second pin-head at the other end of the sulcus was then determined by the periglyph and marked on the glass. By joining the marks on the glass, corresponding to the pin-heads in the brain, the angle which this line formed

with the straight line which passed through the hinder pin-head (the "intraparietal angle"), was produced on the varnished sheet of glass, and could be easily measured. The following are the results which were obtained by this method:—

INTRAPARIETAL ANGLE.

	Male.		Female.	
	Number of Hemi-spheres.	Average Angle.	Number of Hemi-spheres.	Average Angle.
Adult human brain, ...	23	20°·3	11	17°·9
Fœtal brains (from eighth month to full-time), .	11	17°·2	16	13°·4

It will be apparent that the greater this angle is, the greater must be the obliquity of the sagittal part of the intraparietal sulcus. Such being the case, it is interesting to observe that it is not the female (as Rudinger has said) which has the most oblique fissure, but the male, and this is seen both in the fœtus and the adult. Further, it is important to note that the fœtal brain exhibits less obliquity in the direction of the sagittal part of the intraparietal sulcus than the adult.

As for the anthropoid brains I found only one chimpanzee hemisphere in which the hinder end of the sulcus was nearer to the mesial border than the anterior end. The intraparietal angle in this specimen was 20° (fig. 36, p. 204, right hemisphere). In four orang hemispheres, and in one chimpanzee hemisphere, the sulcus ran parallel to the mesial border, whilst in two chimpanzee hemispheres the hinder end of the sulcus was further distant from the mesial border than the anterior end. If, therefore, in the brains of the distinguished men referred to by Rudinger the direction of the sagittal part of the intraparietal sulcus is such as he describes, it must be regarded not as high character but as an approximation to the anthropoid and infantile types.

IX. **Length of the Sagittal part of the Intraparietal Sulcus.**—While engaged in the determination of the intraparietal angle, and the relative size of the arcus parieto-occipitalis, I also made a series of measurements of the length of the sagittal part of the sulcus. A pin being introduced into the hemisphere at either end of the furrow, the distance between these was ascertained by means of a tape measure, without any attempt being made to follow the flexuosities of the fissure. These measurements have been reduced in the following Table to relative results or indices by assuming the mesial length of the hemisphere to be 100.

Relative Length of the Sagittal Part of the Intraparietal Sulcus.

Mesial Length of the Hemisphere = 100.

	Male.		Female.	
	Number of Hemispheres.	Average Length-Index.	Number of Hemispheres.	Average Length-Index.
Adult human brain, ...	15	22·2	13	22·7
Fœtal human brain (from eighth month to full-time),	10	24·2	14	24·6
Chimpanzee, ...	—	—	4	20·4
Orang, ...	4	25·7	—	—

X. **Summary.**—1. The intraparietal sulcus, single and continuous in some of the lower apes (*e.g.* Cebus), becomes broken up in the human brain into a group of furrows which present different relations to each other in different cases.

2. Three of the elements of the sulcus in the human brain, viz. the sulcus postcentralis inferior, the ramus horizontalis, and the ramus occipitalis, are disrupted portions of the original fissure; one, the sulcus postcentralis superior, is a superadded element.

3. In the development of the sulcus in the human fœtal brain all the four segments of the sulcus have as a rule an independent origin, although

as Pansch has shown the sulcus postcentralis inferior and the sulcus horizontalis very frequently appear as one continuous furrow.

4. The sulcus postcentralis inferior usually appears first; then the ramus horizontalis and ramus occipitalis; and last of all the sulcus postcentralis superior.

5. In Cebus there is no sulcus postcentralis superior; it is present, however, in most of the old world apes, *e. g.* the baboon, macaque, gibbon, chimpanzee, orang, and gorilla.

6. In the chimpanzee and orang there is reason to believe that this segment of the postcentral sulcus consists of two elements—one placed above the other.

7. Eberstaller's third and lowest segment of the postcentral sulcus (viz. the sulcus postcentralis transversus) is not only present in man but also in the majority of the old world apes.

8. In the apes the intraparietal sulcus is deeper than the fissure of Rolando; the opposite is the case in man. This would seem to indicate that the morphological value of these sulci is different in man and the apes. The phylogeny and ontogeny of these furrows are in apparent variance with each other. The fissure of Rolando appears first on the developing cerebrum of the human fœtus, yet it is the intraparietal sulcus which first makes its appearance in the evolution of the primate cerebrum.

9. Putting aside for the present the ramus occipitalis we meet in the adult human brain with every possible form of combination of the remaining three segments of the sulcus.

10. The most common combination is that in which they are all (superficially at least) connected together. This was present in 60·3 per cent. of the adult hemispheres examined.

11. In man there appears to be a general tendency towards a union of the two originally distinct postcentral elements of the sulcus and a divorce from the lower of these of the ramus horizontalis.

12. It seems very probable that a more extended investigation into the arrangement of the intraparietal sulcus may establish marked racial and sexual distinctions in the manner of grouping of its different segments.

13. The ramus occipitalis was connected with the ramus horizontalis in 63·7 per cent. of the adult human hemispheres examined.

14. The union between these two segments of the sulcus, as Ecker and Wilder have shown, is much more common on the left side than on the right side.

15. The sulcus occipitalis transversus of Ecker is not the homologue of the "Affenspalte" in the apes, but merely a terminal bifurcation of the ramus occipitalis.

16. This view of the sulcus transversus occipitalis is borne out not only by the phylogenetic but also by the ontogenetic evidence at our disposal (*vide* from p. 220 to p. 234).

17. Eberstaller's views in regard to the preponderance of the inferior parietal lobule in the human brain are apparently correct.

18. The presence of deep annectant gyri in the course of the sagittal part of the intraparietal sulcus are not characteristic of man alone. They may be seen in the brain of the chimpanzee, and occasionally also in the brain of the baboon.

19. In the adult brain the relative size of the first parieto-occipital annectant gyrus is not appreciably different in the two sexes.

20. This gyrus is, however, relatively more bulky in the anthropoid ape than in man.

21. The obliquity of the sagittal portion of the intraparietal sulcus is more marked in the male than in the female.

22. In the anthropoid apes the sagittal part of the sulcus assumes a more sagittal direction than in man.

23. The relative length of the sagittal portion of the sulcus is greater in the human fœtus than in the adult.

CHAPTER V.

THE PRÆCENTRAL AND OTHER SULCI ON THE EXTERNAL SURFACE OF THE FRONTAL LOBE.

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I. **General Statement.**—Pansch compared the præcentral sulcus (his first "Primärfurche") with the intraparietal sulcus (his third "Primärfurche), and stated that they are formed on a "completely similar, and almost symmetrical" plan.* Certainly, the correspondence in the disposition of the several parts of these two furrows is very marked, although this correspondence does not lie altogether in the lines laid down by Pansch. The præcentral sulcus presents a vertical part which limits the anterior cerebral convolution in front; the intraparietal sulcus possesses a vertical portion which bounds the posterior central convolution behind. Each of these vertical portions, together with the fissure of Rolando (the second Primärfurche), which lies between them, is composed of two developmentally distinct pieces. In the case of the intraparietal sulcus these are termed the sulcus postcentralis inferior, and the sulcus postcentralis superior, and

* "Ueber die typische Anordnung der Furchen und Windungen," &c., &c. Archiv für Anthropologie; Dritter Band; p. 235. 1869.

in the course of development they usually become united. The two portions of the vertical part of the præcentral furrow are termed the sulcus præcentralis inferior and the sulcus præcentralis superior. These differ from the corresponding parts of the intraparietal sulcus, in so far, that in their further development they, as a rule, remain distinct.

But, in the intraparietal sulcus we also recognize a sagittal part, which is developed in two portions, viz. a ramus horizontalis and a ramus occipitalis. These stand in more or less direct connexion with each other, and also with the sulcus postcentralis inferior. In the frontal lobe similar sulci, which divide its outer surface into an upper and a lower field, may be recognized. These are—(1) a short horizontal or oblique furrow in direct connexion with the upper end of the sulcus præcentralis inferior, which extends forwards into the middle frontal convolution, and which may therefore be compared with the ramus horizontalis of the parietal lobe; and (2) in front of this, and usually in the same line with it, the sulcus frontalis medius of Eberstaller. A still further feature of similarity between these systems of sulci may be noted in the fact, that the sagittal portion of each furrow, as it approaches the extremity of the cerebrum, ends in a terminal bifurcation, developed in a precisely similar manner in each instance. In the case of the intraparietal sulcus this forms the sulcus occipitalis transversus of Ecker; in the case of the sulcus frontalis medius it forms the sulcus fronto-marginalis of Wernicke (fig. 52, p. 245).

There is one point, however, in which this comparison between the intraparietal and præcentral systems of sulci fails. In the parietal lobe the ramus horizontalis and the ramus occipitalis are developed at the same time, and in the lower primates they are directly continuous with each other. They must, therefore, be considered as possessing an equal morphological value. In the frontal lobe, however, the sulcus frontalis medius is on a different morphological footing from the ramus horizontalis of the inferior præcentral sulcus. In the first place it is, as a general rule, later in making its appearance, and in the second place, although it may be recognized as a distinct element in certain of the anthropoid apes, it is totally absent in the lower apes. From this statement it will be seen that the conclusions at which I have arrived regarding the ontogeny and phylogeny of the sulcus

frontalis medius are altogether opposed to those entertained by Eberstaller. I shall state fully the grounds upon which my views are based when I come to deal with the development of the frontal furrows in the human fœtus, and their arrangement in the apes.

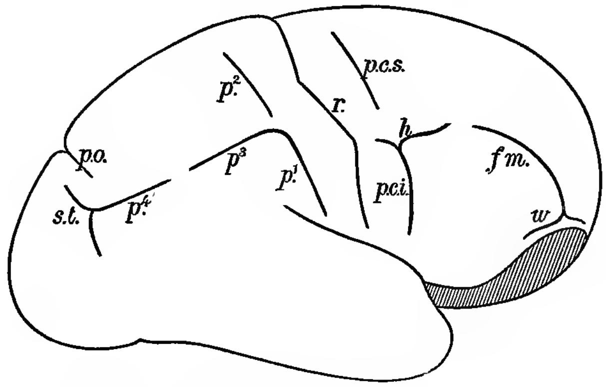


Fig. 52.—Diagram to show correspondence between the præcentral and intraparietal systems of furrows.

r. . . . Fissure of Rolando.
p. c. s. . Sulcus præcentralis superior.
p. c. i. . Sulcus præcentralis inferior.
h. . . . Ramus horizontalis of the sulcus præcentralis inferior.
f. m. . Sulcus frontalis medius.
w. . . . Fronto-marginal sulcus of Wernicke.
*p.*¹ . . Sulcus postcentralis inferior of the intraparietal sulcus.
*p.*² . . Sulcus postcentralis superior of the intraparietal sulcus.
*p.*³ . . Ramus horizontalis of the intraparietal sulcus.
*p.*⁴ . . Ramus occipitalis of the intraparietal sulcus.
s. t. . . Sulcus occipitalis transversus of Ecker of the intraparietal sulcus.
p. o. . . Parieto-occipital fissure.

The first and second frontal furrows have also to be considered in our study of the outer surface of the frontal lobe. Speaking of the connexion which exists between these furrows and the præcentral sulcus, Eberstaller remarks that the first frontal furrow stands in the same relationship to the sulcus præcentralis superior, as the second frontal furrow to the sulcus præcentralis inferior. This can hardly be said to be the case. The basal or posterior part of the first frontal furrow is, in most cases, completely identified with the upper præcentral sulcus. The connexion between the second frontal furrow and the lower præcentral furrow is by no means intimate. A fortuitous communication is in many cases established between the two, but they are, nevertheless, morphologically distinct fissural elements.

Between the first frontal furrow and the mesial margin of the hemisphere there are usually present a series of small irregular depressions or sulci which follow each other in linear order, and partially divide the first frontal convolution into two parts. In some cases these are observed to run into each other, and form a continuous furrow which effects a very complete subdivision of the superior frontal convolution. These sulci have not received the attention they deserve, as there is reason to believe their degree of development gives a clue to the determination of high and low types of cerebrum.

The different elements of the system of furrows on the outer surface of the frontal lobe are not all equally important, and the assigning to each its proper morphological value is no easy matter. The development of the frontal sulci is subject to very considerable variation, and it is only when we associate the evidence it affords with that obtained by the study of the frontal sulci in the different groups of apes that we are able to arrive at satisfactory conclusions. The sulcus præcentralis inferior and the sulcus frontalis secundus are the furrows which must be regarded as holding first rank; the sulcus præcentralis superior and the sulcus frontalis primus possess an inferior status; next in point of morphological importance comes the sulcus frontalis medius; and lowest in the scale are the irregular sulci which impress the first frontal convolution.

II. **Sulcus Præcentralis Inferior** (fig. 53, *p. c. i.*).—This sulcus presents a vertical, and a more or less horizontal portion, and these are, as a rule, in direct and uninterrupted continuity with each other.

The vertical limb is placed in front of the lower part of the ascending frontal convolution, and rarely extends higher than one-third of the distance between the Sylvian fissure and the mesial border of the hemisphere. In almost every case it is curved, so that it is convex to the front and concave towards the back, and its general direction is somewhat variable. Sometimes it runs parallel to the lower part of the fissure of Rolando; in other cases it inclines slightly forwards as it ascends.

In many cases the vertical limb of the inferior præcentral sulcus is shortened by a deficiency in its lower part, but it never, of itself, elongates

so as to cut its way into the fissure of Sylvius. Still, in many cases an indirect communication is established between the inferior præcentral sulcus and Sylvian fissure. As Eberstaller has pointed out, this connexion may be brought about in two ways, viz. by the intervention of one or other of two furrows which he has described under the names of the inferior transverse furrow of Rolando and the sulcus diagonalis.

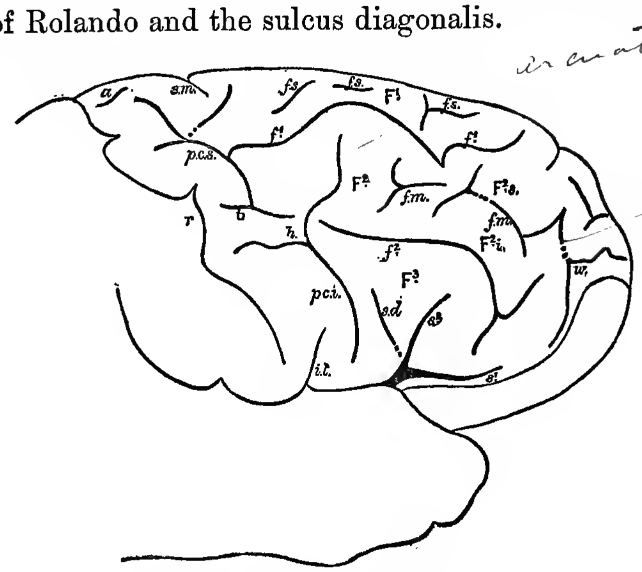


FIG. 53.—Profile view of the frontal lobe of an adult female cerebrum. Drawn by the American apparatus for tracing orthogonal projections of the skull. The cerebrum was adjusted in the apparatus with its upper margin somewhat raised, in order that sulci close to the mesial border might be brought into the sketch. The dotted connexions between portions of the sulci indicate the position of the deep interrupting annectant gyri.

r. . . . Fissure of Rolando.
a. . . . Sulcus præcentralis marginalis.
p. c. s. . . Sulcus præcentralis superior.
b. . . . Sulcus præcentralis medius (?).
h. . . . Ramus horizontalis.
p. c. i. . . Sulcus præcentralis inferior.
i. t. . . . Inferior transverse sulcus of the fissure of Rolando (Eberstaller).
f. s. . . . Sulci frontalis mesialis.
s. m. . . Sulcus præcentralis medialis (Eberstaller).
f.[1] . . . Sulcus frontalis primus.
F.[1] . . . Superior frontal convolution.
f. m. . . Sulcus frontalis medius of Eberstaller.
w. . . . Fronto-marginal sulcus of Wernicke.
F.[2] . . . Middle frontal convolution.
F.[2] *s.* . . Superior part of middle frontal convolution.
F.[2] *i.* . . Inferior part of middle frontal convolution.
f.[2] . . . Sulcus frontalis secundus.
s. d. . . . Sulcus diagonalis of Eberstaller.
s[2]. . . . Ramus ascendens of the Sylvian fissure.
s.[1] . . . Ramus horizontalis anterior of the Sylvian fissure.

The inferior transverse sulcus of Rolando is a small furrow which cuts the margin of the fronto-parietal operculum below the lower end of the fissure

of Rolando, and takes an oblique course upwards and forwards towards the lower end of the sulcus præcentralis inferior (fig. 53, *i. t.*). As we have already noted in Chapter III., the partial union of the fissure of Rolando with this furrow leads, in many cases, to a superficial connexion between the former and the fissure of Sylvius. In other cases, however, where the inferior transverse furrow is strongly developed, and, perhaps, placed somewhat further forward than usual, it may open above into the sulcus præcentralis inferior, and carry it downwards into the Sylvian fissure. When this occurs the point of junction between the inferior transverse furrow and the inferior præcentral sulcus is always marked by a deep annectant gyrus. It is interesting to observe that, in cases where the inferior transverse furrow is strongly developed, it is usual to find the vertical limb of the sulcus præcentralis inferior shortened. Eberstaller has also noted this. He says: "An manchen Gehirnen konnte ich auch beobachten, dass eine stark entwickelte *c. t. r.* (*i. e.* inferior transverse furrow), gleichzeitig mit rudimentärer Ausbildung des unteren Abschnittes der Präcentralfurche sich vorfand, also gewissermassen die eine die andere in ihrer Ausbildung behinderte, beziehungsweise compensirte."*

The sulcus diagonalis of Eberstaller is placed in front of the inferior præcentral fissure, and divides the pars basilaris of the inferior frontal convolution into two triangular fields (fig. 53, *s. d.*). Its lower end, as a rule, opens into the posterior horizontal or the anterior ascending limb of the Sylvian fissure. From this it ascends obliquely upwards and backwards towards the inferior præcentral sulcus. Sometimes it opens into this, and then a communication between the præcentral sulcus and the Sylvian fissure is the result. A deep annectant gyrus invariably marks its point of junction with the former.

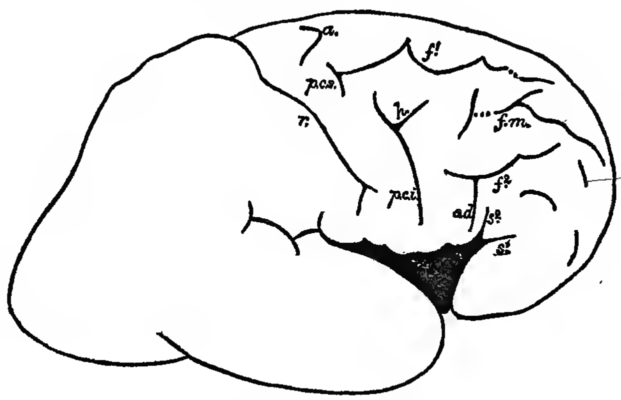
An examination of fifty adult hemispheres, with the view of determining the frequency of the communication between the inferior præcentral sulcus and the fissure of Sylvius has afforded the following results:—

1. In 58 per cent. the lower end of the inferior præcentral was free, and in no way connected with either the inferior transverse furrow of the fissure of Rolando or the sulcus diagonalis.

* Das Stirnhirn, p. 62. Leipzig, 1890.

2. In 22 per cent. the inferior præcentral furrow was brought into connexion with the Sylvian fissure through the intervention of the sulcus diagonalis.

3. In 20 per cent. the inferior præcentral sulcus was brought into connexion with the Sylvian fissure through the intervention of the inferior transverse furrow of the fissure of Rolando.



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W

FIG. 54.—Right cerebral hemisphere from a fœtus in the eighth month of development. Drawn by the American apparatus for tracing orthogonal projections of the skull. The dotted connexions between certain of the furrows indicate the position of deep annectant gyri. The sulcus diagonalis is vertical in its direction, and joins the inferior frontal sulcus.

r.	Fissure of Rolando.	*f.*¹	Sulcus frontalis primus.
a.	Sulcus præcentralis marginalis.	*f. m.*	Sulcus frontalis medius.
p. c. s.	Sulcus præcentralis superior.	*f.*²	Sulcus frontalis secundus.
h.	Ramus horizontalis of the sulcus præcentralis inferior.	*s.*²	Anterior ascending limb of the Sylvian fissure.
p. c. i.	Sulcus præcentralis inferior.	*s.*¹	Anterior horizontal limb of the Sylvian fissure.
s. d.	Sulcus diagonalis of Eberstaller.	W	frontomarginal S. of Wern

I may further mention that, in one hemisphere (not included in the above series), there was established a double connexion with the Sylvian fissure through the intermediation of both the inferior transverse furrow and the sulcus diagonalis; in another case both the fissure of Rolando and the inferior præcentral furrow joined the inferior transverse furrow, and presented a common communication with the fissure of Sylvius.

Giacomini* has stated that the sulcus præcentralis inferior anastomoses in 68 per cent. of the hemispheres examined, with the anterior limb of the Sylvian fissure, and Eberstaller thinks that this may be explained by the junction effected through the sulcus diagonalis. This mode of union is much less frequent in its occurrence. There are many instances, however, in which the sulcus diagonalis assumes a very considerable length, and

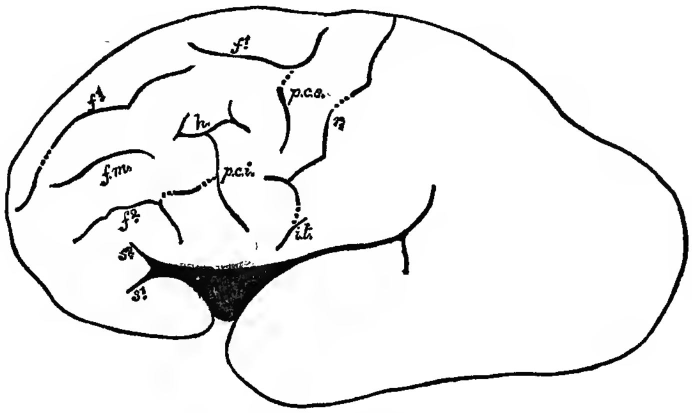


FIG. 55.—Left cerebral hemisphere from a fœtus in the eighth month of development. Drawn by the American apparatus for tracing orthogonal projections of the skull. The dotted connexions between certain of the furrows indicate the position of deep annectant gyri.

r.	Fissure of Rolando.	*f.*[1]	Sulcus frontalis primus.
p. c. s.	Sulcus præcentralis superior.	*f. m.*	Sulcus frontalis medius.
h.	Ramus horizontalis of the sulcus præcentralis inferior.	*f.*[2]	Sulcus frontalis secundus.
p. c. i.	Sulcus præcentralis inferior.	*s.*[2]	Anterior ascending limb of the Sylvian fissure.
i. t.	Inferior transverse furrow of the fissure of Rolando.	*s.*[1]	Anterior horizontal limb of the Sylvian fissure.

whilst it keeps separate from the præcentral sulcus, opens into the inferior frontal furrow (fig. 54, *s. d.*). When this occurs, the sulcus diagonalis is very apt to be mistaken for the sulcus præcentralis inferior, and it is just possible that Giacomini may have included it in his statistics as such.

* Varietà delle circonvoluzioni cerebrali dell' uomo. Turin, 1882.

The ramus horizontalis, into which the upper end of the vertical part of the inferior præcentral furrow opens, presents a great variety of conditions in the adult brain, and, as a consequence it has, as a rule, escaped recognition. It is placed, in relation to the upper end of the ramus verticalis, somewhat after the manner of the horizontal limb of the letter T or F (fig. 53, *h.*, p. 248). As a rule, it is not horizontal in its direction, but is directed from behind obliquely upwards and forwards into the posterior part of the middle frontal convolution. This obliquity is, in a measure, due to the backward curve of the vertical limb of the fissure, and is not so marked in the fœtal as in the adult brain (figs. 54 and 55, *h.*, pp. 250 and 251).

Both Eberstaller and Hervé have taken notice of the ramus horizontalis of the inferior præcentral sulcus. The former observer says: "Aus der unteren Präcentralfurche geht häufig ausser der unteren Stirnfurche ungefähr von derselben Stelle aus noch eine zweite Furche nach vorne ab. Während aber die untere Stirnfurche unter rechtem Winkel sie verlässt, zieht das Furchenstück, von dem ich jetzt reden will, schräg nach vorne und oben in die mittlere Stirnwindung hinein."* He terms it the "ramus anterior."

Hervé's remarks upon the horizontal portion of the inferior præcentral sulcus are somewhat ambiguous. In page 70 of his work upon the "Convolution of Broca," he states, that "it is not very rare" to find the "bent branch" of this furrow; whilst in page 48, in a footnote, he mentions that "in man it appears that the branch in question is entirely effaced, at least in many cases."

I have very rarely seen the horizontal portion of the inferior præcentral furrow absent, although an increase in the degree of its obliquity frequently gives rise to a difficulty in its recognition. As a rule, it has the appearance of a terminal bifurcation of the upper end of the vertical portion of the furrow, the diverging limbs of which are widely spread out from each other. In most cases the hinder limb is the shorter of the two, and often it lies more in a line with the vertical portion of the sulcus than the longer more horizontally directed anterior limb. This is the condition which is

* Das Stirnhirn, p. 61. Leipzig, 1890.

exhibited in Eberstaller's schematic representation of the outer surface of the hemisphere. It is also seen in figure 54, p. 250, in Plate i., figure 33, and in Plate iv., figure 1. The condition of the sulcus, which I consider typical, although it is not the one which is most frequently met with, is seen in figure 53, page 248, and also, to a less extent, in figure 55, page 251.

Fifty adult hemispheres were examined with the view of determining the frequency of this ramus horizontalis of the inferior præcentral sulcus and its relations to the vertical stem of the fissure. The following are the results obtained:—

1. Present in complete and uninterrupted union with the vertical stem, 72·3 per cent.

2. Present in incomplete union with the vertical stem—a deep annectant gyrus marking the point of junction—8·5 per cent.

3. Present, but completely separated from the vertical stem by a superficial gyrus, 2·1 per cent.

4. Present, but presenting a deep annectant gyrus at the base of its anterior branch, 4·3 per cent.

5. Present, but presenting a deep annectant gyrus at the base of its posterior branch, 4·3 per cent.

6. Completely absent, 8·5 per cent.

The fact that it may be completely or partially cut off from the vertical limb, and also the occasional partial separation of its anterior or posterior branches, may be explained, as we shall afterwards see by a study of the development of the furrow.

I am inclined to believe that in certain cases where the ramus horizontalis has been observed altogether separate from the vertical stem, it has been described as the sulcus præcentralis medius. Such appears to me to be the case in the "second type" of præcentral sulcus described by Sernoff —the figure of which I am able to introduce through the courtesy of the author (fig. 56, *p. r. m.*, p. 254). Again, in two other figures, which he gives in page 16 of his work on the "Individual types of the convolutions of the

brain in man," he shows conditions which are clearly cases of complete union and complete separation of the horizontal and vertical portions of the inferior præcentral sulcus.* In the great majority of Sernoff's illustrations the ramus horizontalis is indicated with clearness and exactitude (*vide* his figs. 7 to 16, pp. 18 to 23, in which the different forms of the sulcus are shown with great accuracy).

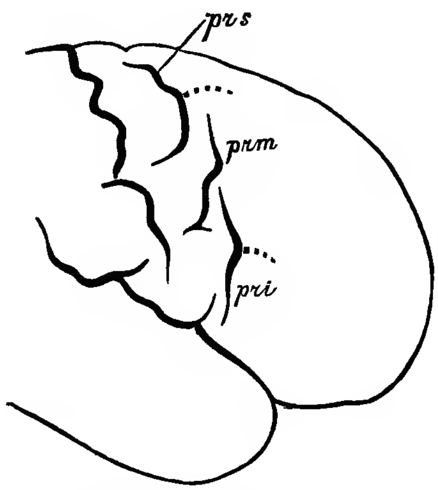


FIG. 56.—Sernoff's second type of præcentral sulcus. *p. r. i.*, sulcus præcentralis inferior; *p.r.s.*, præcentralis superior; *p. r. m.*, apparently a detached ramus horizontalis of the sulcus præcentralis inferior.

The sulcus præcentralis inferior is frequently connected with the sulcus frontalis secundus. So common is this condition that Jensen was induced to apply to the compound furrow arrangement thus produced the term of "unterer Stirnfurchencomplex."† But, as Eberstaller has shown, although it is more common to find the hinder end of the second frontal furrow communicating with the præcentral sulcus than free, in the great majority of cases the union is not complete, seeing that a distinct deep annectant gyrus is placed at the point of junction. In my study of this point I

* Individualniye tipy mozgovykh izvilin u tchelovêka. Moskow, 1877.

† Die Furchen und Windungen der menschlichen Grosshirn-Hemisphären, von Dr. Julius Jensen, p. 14. Berlin, 1871.

examined fifty adult hemispheres, twelve full-time fœtal hemispheres, and eighteen eighth-month fœtal hemispheres, with the following results:—

1. The sulcus frontalis secundus stood completely apart from the inferior præcentral sulcus, and was separated from it by a superficial gyrus in—

32·6	per cent.	of the adult hemispheres,
41·7	,,	of the full-time fœtal hemispheres,
50·2	,,	of the eighth-month fœtal hemispheres.

From this we may infer that the union is frequently deferred until after birth. Eberstaller states that this condition is only present in 24 per cent., or in about one-fourth of the cases examined. The percentage which I have obtained is considerably higher. A good example of the complete separation of the two sulci is seen in figure 53, *f.*², p. 248.

2. The sulcus frontalis secundus may either be joined to the vertical stem, or to the anterior branch of the ramus horizontalis of the sulcus præcentralis inferior. The former arrangement is seen in Plate IV., figure 1, the latter in Plate I., figure 33. The following are the conditions under which the union may take place:—

(*a*) Complete union to the vertical stem of the sulcus præcentralis inferior.

Adults,	28·3 per cent.
Full-time fœtuses,	41·7 ,,
Eighth-month fœtuses,	16·6 ,,

(*b*) Incomplete union to the vertical stem of the sulcus præcentralis inferior.

Adults,	21·7 per cent.
Full-time fœtuses,	0·0 ,,
Eighth-month fœtuses,	16·6 ,,

In these a deep annectant gyrus intervened between the two sulci under consideration.

(*c*) Complete union to anterior branch of the ramus horizontalis of the inferior præcentral sulcus. This connexion usually takes place near the base of the anterior branch of the ramus horizontalis.

Adults, ...	6·5 per cent.
Full-time fœtuses, ...	8·3 ,,
Eighth-month fœtuses, ...	0·0 ,,

(*d*) Incomplete union to the anterior branch of the ramus horizontalis—a deep annectant gyrus intervening between the two.

Adults, ...	10·9 per cent.
Full-time fœtuses, ...	8·3 ,,
Eighth-month fœtuses, ...	16·6 ,,

I may further mention, that in six negro hemispheres which were examined, the union between these two furrows was only observed in two.

In some cases a connexion is also established between the ramus horizontalis of the inferior præcentral furrow and the sulcus frontalis medius of Eberstaller. This arrangement we shall discuss when we come to study the latter sulcus.

III. **Sulcus Præcentralis Superior.**—In its simplest form this sulcus is present in the shape of a continuous vertical furrow which lies in front of the anterior central convolution in its upper half. Its upper end falls short of the mesial border of the hemisphere, whilst its lower end may be placed above and between the two branches of the ramus horizontalis of the sulcus præcentralis inferior (fig. 53, *p. c. s.*, p. 248), or it may reach a lower level and lie behind both (fig. 57, *p. c. s.*, p. 259). The sulcus frontalis primus joins it about its middle, and usually passes uninterruptedly into it.

But whilst this may be considered the typical condition of the sulcus præcentralis superior the arrangement is subject to much modification. Three principal varieties may be recognized.

1. In the first variety the furrow is broken up into two pieces—a superior and an inferior—by the presence of a deep annectant gyrus. This interruption takes place immediately above the junction of the sulcus frontalis primus, which passes continuously into the inferior portion of the

sulcus. In certain cases the upper portion of the superior præcentral sulcus is completely cut off from the lower piece by the presence of this annectant gyrus on the surface.

2. In the second variety the deep annectant gyrus is placed below the junction of the first frontal sulcus, which is therefore brought into direct and uninterrupted continuity with the upper part of the superior præcentral sulcus, whilst the lower portion is partially separated from both (fig. 55, p. 251, *p. c. s.*). This variety is not so common as the first.

3. In the third variety we have the cruciform arrangement mentioned by Eberstaller. The sulcus frontalis primus is carried backwards beyond the line of the superior præcentral furrow. In this case the upper and lower portions of the upper præcentral sulcus are separated from the frontal furrow by deep annectant gyri. In this variety one or both of these bridging gyri may reach the surface, and produce a complete separation of the fissural system into two or three parts (fig. 59, p. 262).

The close association of the first frontal sulcus with the superior præcentral furrow is one of the most constant features of this fissural system; and this is still further emphasized when we study the development of the two furrows, and note their rudimentary condition in the lower members of the primate group. Eberstaller considers the connexion to be an absolutely constant one. Speaking of the sulcus frontalis primus he remarks: "Ihr hinteres Ende geht fast immer Beziehungen zur oberen Präcentralfurche ein und selbst, wenn aus der Wurzel der mittleren Stirnwindung ein Zuzug zur oberen Stirnwindung erfolgt, welcher Zuzug sich dann als 'laterale Wurzel' der letzeren präsentirt, bleibt noch immer ein hinteres Stück unserer Furche mit der Præcentralis superior in Verbindung."* That this is true in the vast majority of cases there cannot be the least doubt, but it is right to mention that, in rare instances, I have seen the posterior end of the sulcus frontalis primus cut off from the sulcus præcentralis superior by a deep, or even by a superficial annectant gyrus.

In addition to the main portions of the præcentral furrow (viz. the sulcus præcentralis inferior and the sulcus præcentralis superior), two other

* Das Stirnhirn, p. 69. Leipzig, 1890.

pieces may be developed in relation to the upper and lower extremities of the sulcus præcentralis superior. Of these, the latter is named the sulcus præcentralis medius, and will require separate notice. The other is a small furrow which is very frequently observed between the upper end of the superior præcentral sulcus and the mesial margin of the hemisphere (fig. 53, p. 248; fig. 54, p. 250; and fig. 59, p. 262, *a.*). It may either stand separate, or it may join the upper extremity of the superior præcentral sulcus. A deep annectant gyrus always marks the point of union. We may distinguish this little furrow by the name of sulcus præcentralis marginalis. It must not be confounded with the sulcus præcentralis medialis, or the anterior limiting furrow of the paracentral lobule which cuts the mesial border of the hemisphere in front of the upper extremity of the superior præcentral furrow (fig. 53, p. 248, *s. m.*).

IV. **Sulcus Præcentralis Medius.**—This is not a constant sulcus, and the term is not always applied to the same fissural element. As we have noted, the separation of the horizontal limb of the inferior præcentral sulcus, by the appearance on the surface of the deep annectant gyrus, which occasionally intervenes between it and the vertical limb, produces a furrow which holds an intermediate position, and to which the term sulcus præcentralis medius has been applied. An increase in the obliquity of the furrow which brings it more into a line with the vertical portions of the fissural system is very common, and tends to obscure its real nature. As a rule its lower end lies behind the upper extremity of the vertical limb of the inferior præcentral sulcus, whilst its upper end is placed in front of the inferior extremity of the sulcus præcentralis superior (fig. 56, *p. r. m.*, p. 254). The sulcus præcentralis medius, described by Eberstaller, is of this nature.*

The second form of sulcus præcentralis medius is of a totally different character. It, apparently, belongs more to the upper than to the lower main portion of the præcentral sulcus. It is well seen in figure 57. It is usually placed altogether behind the upper part of the sulcus præcentralis

* Das Stirnhirn, p. 61. Leipzig, 1890.

inferior, and is very commonly connected, as is shown in the figure, with the lower end of the sulcus præcentralis superior.

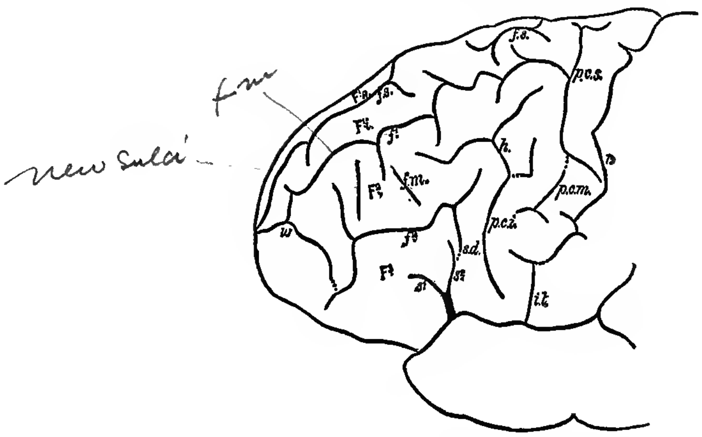


Fig. 57.—Left hemisphere of male infant, six months old. Drawn by the American apparatus for tracing orthogonal projections of the skull. The dotted lines indicate the position of the deep annectant gyri.

r.	Fissure of Rolando.	*s. d.*	Sulcus diagonalis.
p. c. s.	Sulcus præcentralis superior.	*F.*[1] *s.*	Upper part of the superior frontal gyrus.
p. c. m.	Sulcus præcentralis medius.	*f. s.*	Sulcus frontalis mesialis.
p. c. i.	Sulcus præcentralis inferior.	*F.*[1] *i.*	Lower part of the superior frontal gyrus.
i. t.	Inferior transverse furrow of the fissure of Rolando.	*f.*[1]	Sulcus frontalis primus.
		F.[2]	Middle frontal gyrus.
s.[2]	Ascending limb of the Sylvian fissure.	*f.*[2]	Sulcus frontalis secundus.
s.[1]	Anterior horizontal limb of the Sylvian fissure.	*F.*[3]	Inferior frontal gyrus.
		w.	Fronto-marginal sulcus of Wernicke.

Either form of sulcus præcentralis medius may produce a long continuous furrow parallel to the fissure of Rolando by becoming superficially joined at either end to the superior and inferior præcentral sulci.

At the beginning of this chapter we instituted a comparison between the intraparietal and præcentral systems of furrows. There are two points in which we now see they stand out in marked contrast—(1) A continuous postcentral sulcus, by the union of its upper and lower portions, occurs in 71·4 per cent. of the hemispheres examined, whereas a continuous præcentral sulcus is only present in 9·3 per cent. of the hemispheres examined; (2) in the case of the postcentral sulcus the two portions unite directly; in

the case of the præcentral sulcus the union is brought about either by an upward rotation of the horizontal limb of the inferior sulcus, or by the introduction of a new element which acts as a connecting link between the two parts of the furrow.

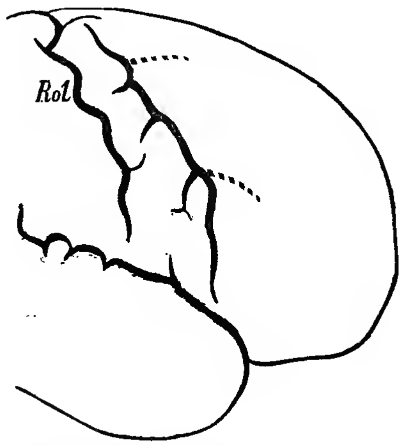


FIG. 58.—Figure from Sernoff's work, reproduced by permission. It shows a continuous præcentral sulcus, produced by a blending of its several elements.

V. **Sulcus Frontalis Secundus.**—A very essential point to observe in connexion with the inferior frontal sulcus is that its hinder end is placed below the horizontal part of the inferior præcentral sulcus (fig. 53, *f.*[2], p. 248). From this it proceeds forwards until it reaches a point immediately above the ascending limb of the Sylvian fissure. Here it turns slightly downwards, and ends by bifurcating into two branches, which spread out widely from each other and form a terminal transverse piece for the furrow. The lower of the two branches resulting from this bifurcation cuts into the pars triangularis of the inferior frontal convolution between the two anterior limbs of the Sylvian fissure (fig. 53). If the lips of the inferior frontal sulcus be widely separated from each other, it is seen to possess a considerable depth, whilst its walls interlock with each other through the presence of alternating gyral eminences. In some cases also, as Eberstaller has pointed out, it may be partially interrupted by one or two deep annectant gyri. One of these occurs midway between the two extremities of the furrow, whilst the other

is placed so as to block the free communication between the sagittal portion of the furrow and its transverse terminal part.

According to the presence or absence, and also the degree of development of these annectant gyri, we may meet with several varieties of the inferior frontal sulcus. The examination of fifty-four hemispheres afforded the following results:—

1. In rather more than half of the hemispheres examined (50·8 per cent.), the furrow was equally deep throughout, and not interrupted by annectant gyri.

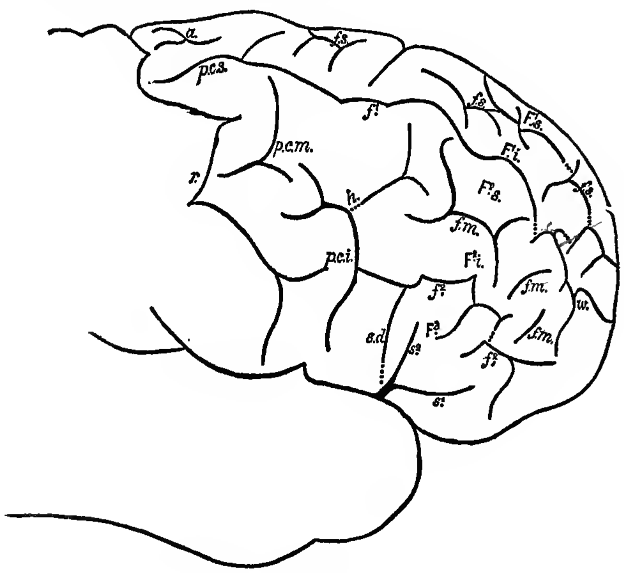
2. The anterior deep annectant gyrus was present in 30 per cent., and was so placed that it partially cut off the transverse terminal part from the sagittal stem. In only one hemisphere did this gyrus rise to the surface and produce a complete divorce of the terminal transverse portion from the main part of the sulcus.

3. In eleven cases (or 19·2 per cent.) the middle annectant gyrus was present. In five of these (8·7 per cent.) it remained below the surface, and only partially interrupted the sulcus; in six (10·5 per cent.) it reached the surface and completely broke up the sagittal stem into an anterior and a posterior portion.

But there are two additional furrows which must be associated with the inferior frontal sulcus, seeing that they undoubtedly belong to the same system, and not unfrequently are directly connected with it. I refer to two short transverse sulci, which are frequently placed in front of the inferior frontal sulcus, in series with and parallel to its transverse terminal part. Eberstaller has recognized the presence of these furrows, but he gives them separate names and an independent position. The first he terms the sulcus radiatus (die radiäre Stirnfurche). By its lower end it cuts, as a rule, into the fore-part of the pars triangularis; by its upper end it frequently joins superficially the sulcus frontalis medius. I have found it present in twenty-nine out of fifty-seven hemispheres examined. Of these it was completely separate from the inferior frontal sulcus in twenty-two cases, whilst in seven it was joined to its anterior extremity—a deep annectant gyrus marking the place of union.

The second and more anterior of the two transverse furrows which lie

in front of the terminal part of the inferior frontal sulcus, Eberstaller has



fm = correct
? new sulci

FIG. 59.

Lateral view of the frontal lobe of an adult male. The outline was obtained by means of the American apparatus for tracing orthogonal projections of the skull.

In this cerebrum the inferior frontal sulcus is evidently connected with Eberstaller's sulcus radiatus and the so-called lateral part of the fronto-marginal sulcus. It presents, therefore, three transverse pieces in connexion with its fore end. The hinder end of the sulcus is also directly and without interruption joined to the vertical stem of the sulcus præcentralis inferior, whilst the sulcus diagonalis runs continuously into it from below.

The cruciform arrangement of the superior præcentral and first frontal sulci is seen.

The front portion of the sulcus frontalis medius is superficially connected with, and runs in the line of, the sulcus frontalis primus. Its place is taken by secondary transverse sulci.

Note the great development of the sulcus frontalis mesialis, and the complete manner in which it divides the first or superior frontal convolution into two gyri.

The dotted lines indicate the position of the deep annectant gyri.

r.	Fissure of Rolando.	*F.*^{1} *s.*	Upper part of the superior frontal gyrus.
a.	Sulcus præcentralis marginalis.	*F.*^{1} *i.*	Lower part of the superior frontal gyrus.
p. c. s.	Basal part of the first frontal furrow.	*f.*^{1}	Sulcus frontalis primus.
p. c. m.	Sulcus præcentralis superior.	*f. m.*	Sulcus frontalis medius.
p. c. i.	Sulcus præcentralis inferior.	*w.*	Sulcus fronto-orbitalis of Wernicke, with anterior part of the sulcus frontalis medius joined to the first frontal sulcus.
h.	Ramus horizontalis.	*F.*^{2} *s.*	Upper part of middle frontal gyrus.
s. d.	Sulcus diagonalis.	*F.*^{2} *i.*	Lower part of middle frontal gyrus.
s.^{2}	Ascending limb of Sylvian fissure.	*f.*^{2}	Inferior or second frontal furrow.
s.^{1}	Anterior horizontal limb of the Sylvian fissure.		
f. s.	Sulcus frontalis mesialis.		

named the "lateral portion of the fronto-marginal sulcus." It is a small

furrow placed close to the superciliary margin of the frontal lobe, and usually in front of the anterior horizontal limb of the Sylvian fissure. It is only present in exceptional cases, and in certain of these it is joined superficially to the transverse furrow which lies behind it (*i. e.* to the sulcus radiatus of Eberstaller).

It must be apparent from what has been said that the sulcus frontalis secundus may appear in one, two, three, four, or even five pieces. In the fifty-seven hemispheres in which I have examined this sulcus I have seen no less than fourteen different varieties resulting from different combinations of its parts, according as the annectant gyri are absent, hidden within the furrow, or on the surface.

When Sernoff* speaks of the sulcus frontalis inferior as being occasionally completely absent, he, no doubt, refers to those cases in which it is broken up into its several parts.

The sulcus diagonalis of Eberstaller very frequently opens into the sulcus frontalis secundus (fig. 59, p. 262). This union may be complete, or interrupted by a deep gyrus. In cases where the junction is effected with a second frontal sulcus which is distinct and separate from the inferior præcentral sulcus an F-shaped furrow is produced, which bends round the ascending limb of the fissure of Sylvius (fig. 54, p. 250). At first sight the condition might readily be mistaken for a doubling of the inferior præcentral furrow.

VI. **Sulcus Frontalis Primus.**—We have noted the intimate relationship which exists between this furrow and the sulcus præcentralis superior. Continuous with the latter behind, it runs forwards with a slight inclination inwards, and, as Eberstaller has pointed out, ends close to the mesial border, about one inch, or rather more, from the superciliary margin (fig. 53, p. 248). In a large number of cases, however, a small furrow presenting the same direction intervenes between its anterior extremity and the frontal pole, and must, in consequence, be regarded as a separate portion of the furrow (fig. 53, p. 248). I have noted the presence of this

* "Individualniye tipy mozgovykh izvilin u tchelovêka." (Individual types of the convolutions of the brain in man). Moskow, 1877.

little sulcus in 27·8 per cent. of the hemispheres examined, although in certain of these it was broken up into two short, more or less transverse depressions.

The main portion of the furrow may be continuous and uninterrupted throughout (27·8 per cent.); much more frequently it is broken up into two (49·2 per cent.) or three pieces (23 per cent.) by deep or superficial annectant gyri, which pass between the superior and middle frontal gyri.

When the interrupting gyri are on the surface the separate pieces of the furrow succeed each other, as a rule, in a very definite manner. In direction they are oblique, and the posterior end of each is placed on the outer side of the anterior extremity of the one behind, whilst the other extremity approaches close to the mesial border of the hemisphere. Eberstaller has also observed this mode of arrangement of the separate pieces of the first frontal furrow in those cases where its continuity is disturbed by the presence of superficial annectant gyri.

In the negro cerebrum this furrow appears to have a greater tendency to break up into separate parts than in the European.

VII. **The Sulcus Frontalis Medius.** Eberstaller* has the credit of having first clearly recognized and described this fissure, although it would seem that it was also independently identified as a distinct fissural integer by Hervé.† It is one of great interest, but in the hands of these two authors it has been assigned, as we shall see later on, an altogether undue importance.

The sulcus frontalis medius traverses the middle frontal convolution in an antero-posterior direction, so as to divide it into an upper and lower portion. Eberstaller describes the furrow in the following terms:—" In its typical form the middle frontal furrow appears generally as a sagittally directed sulcus, which begins in a transversely placed short branch, midway between the anterior central convolution and the orbital border, and ends in a similar transverse branch immediately above

* Ueber Gehirnwindungen.—Oesterreichische aerztliche Vereinszeitung, No. 8, 1884; also Das Stirnhirn, p. 72. Leipzig, 1890.

† La circonvolution de Broca. Paris, 1888.

the orbital border. This furrow shares the peculiarity of a hinder transverse branch, with the upper and lower frontal furrows only; in the case of the latter the transverse branches receive the special names of the upper and lower præcentral furrows."

In my endeavours to ascertain the characters presented by the sulcus frontalis medius, I have followed the same plan which I have adopted in the case of the other furrows I have studied. I have examined sixty-nine hemispheres, and in each case I have sketched the fissure, and taken care to note its component parts, and the connexions it established with neighbouring sulci. The drawings thus obtained I have then classified into groups according to the correspondence in general features presented by the sulcus in different hemispheres. The degree of variability of this sulcus, as established by this method, is very bewildering. In the sixty-nine hemispheres examined, I have met with no less than twenty-seven different varieties of the middle frontal sulcus. It would serve little purpose to give these in detail. I shall therefore confine myself to the conditions which produce this variability—remarking, however, in passing, that a sulcus which assumes so many different forms is not likely to be one of such leading and conspicuous morphological value as Eberstaller and Hervé would have us believe.

A very essential point to note in regard to the sulcus is the fact that it lies in front of the horizontal portion of the inferior præcentral furrow, although, owing to the manner in which the anterior part of the latter is tilted upwards in the human brain, it can hardly be said to show in the adult an exactly similar direction (fig. 53, p. 248). Both, however, tend to cut the middle frontal convolution into an upper and lower portion—the latter in its posterior part, and the former in its fore part. Eberstaller has referred to a small transverse branch with which its hinder end is in continuity. When this is the case (fig. 53, *f. m.*, p. 248), it will be noticed that a deep annectant gyrus always intervenes, and prevents a free union between the two; indeed, in the majority of cases the annectant gyrus is on the surface, and the transverse furrow is thus completely cut off from the sagittal portion of the middle frontal sulcus. A second small transverse furrow, behind that already mentioned, is also almost invariably present,

and a union of the two is by no means uncommon (fig. 59, *f. m.*, p. 262). These small furrows, undoubtedly, belong to the same system as the portion of the sulcus described by Eberstaller. They prolong it backwards, and bring it into close association with the horizontal part of the inferior præcentral sulcus. They are intermediate links, as it were, and the truth of this is to be seen in those rare cases where they are not only joined to each other, but also to the portion of the middle frontal furrow which lies in front of them, and to the horizontal part of the inferior præcentral sulcus which lies behind them. Eberstaller has therefore little reason for comparing the small transverse sulcus, in which he says the middle frontal furrows begins, to the præcentral sulci in their relations to the first and second frontal furrows. In many cases these small transverse sulci establish a superficial connexion with the first and second frontal furrows.

Eberstaller lays considerable stress upon the depth of the sagittal stem of the sulcus. He asserts that it has "meist eine grössere Tiefe, als irgend eine der sagittalen Stirnfurchen, eine Tiefe, wie wir sie, abgesehen, von der Centralspalte, am Stirnhirne nur in der Præcentralis inferior wiederfinden." This is not my experience. As a general rule I have found it shallower than either the second or the first frontal furrows. In a large proportion of cases it is interrupted by one or two deep annectant gyri. These may appear at different places, but, as a rule, one is situated midway between its two extremities, whilst the other is placed at its junction with its anterior terminal cross-piece. It is not very uncommon to find one or both of these annectant gyri on the surface, thus breaking up the furrow into separate pieces. When this occurs the isolated portions of the sulcus tend to assume a more or less transverse direction. Taking into consideration, then, the two pieces of the furrow which lie in front of the horizontal part of the inferior præcentral furrow, it is possible to imagine a hemisphere in which the sulcus frontalis medius is represented by five completely separate portions. I have not met with such a condition, because it would appear that, in cases where there is a tendency for the anterior usually continuous part of the furrow to break up, there is also a concurrent tendency for the hinder usually separate pieces to run into each other. In eight hemispheres, however, I have observed the sulcus in four pieces.

Hervé has also recognized the interrupted form of the sulcus. He says: "Mais sur un grand nombre de cerveaux, et non tous parmi les plus simples, la face convexe de F^2 (*i. e.* the middle frontal convolution) est parcourue en son milieu par une série d'incisures et de sillons isolés, quelquefois continus, qui manifestement la dédoublent sur une partie plus ou moins notable de sa longeur en deux plis distinct."*

The terminal cross-piece which skirts the superciliary margin of the hemisphere is very constant, and has been described by Wernicke as a separate furrow, under the name of the fronto-marginal sulcus. He states, that "sie ist quer gegen den Längsverlauf der Windungen gestellt und schneidet oberhalb der Orbitalkante des Stirnlappens nach rechts und links in die zweite und dritte Stirnwindung ein."† It presents the appearance of being a terminal bifurcation of the sulcus frontalis medius in which the two limbs are widely spread out from each other (figs. 53 and 59, pp. 248 and 262, *w.*). In a large number of cases it is partially cut off from the stem by a deep bridging gyrus. This may rise to the surface, and then the fronto-marginal furrow becomes an independent sulcus.

Eberstaller has rightly called attention to the fact that the outer limb of this terminal bifurcation of the middle frontal sulcus is frequently partially separated from the main stem of the furrow, and also from the inner limb, by a deep bridging gyrus. I have noted this interruption in 20·7 per cent. of the hemispheres examined. This breach of continuity has led Eberstaller to consider that the inner limb of the bifurcation of the main stem is the true continuation of the sagittal part of the furrow. I hardly agree with him in this, seeing that it also may be partially detached (7·2 per cent.). Further, in figure 60 (p. 268), which shows the furrows of the frontal lobe in a fœtal cerebrum, it will be seen that the terminal part of the sulcus frontalis medius turns outwards, and there is as yet no sign of the inner limb of the bifurcation.

In many cases the hinder end of the sulcus frontalis medius is connected with the sulcus frontalis primus (Eberstaller states in 44 per

* La circonvolution de Broca. Paris, 1888, p. 70.

† "Das Urwindungssystem des menschlichen Gehirns," Archiv für Psychiatrie, &c., Band vi., Heft 1, 1875, p. 304.

cent.). It is usually brought about by the transverse portion which is placed in relation to its hinder end, and it does not necessarily bring the two sulci into a direct line with each other. But even in cases where this occurs the union is generally not complete, but is interrupted by the presence of a deep bridging gyrus (fig. 59, p. 262). In rare instances an absolute and uninterrupted continuity may be established (fig. 57, p. 259). In these cases the sulcus frontalis medius is removed from its normal connexions. It lies nearer the mesial border of the hemisphere, and the ground which it usually occupies is traversed by two or three shallow transverse sulci (figs. 57 and 59, pp. 259 and 262, *f. m.*) which lie in series with each other.

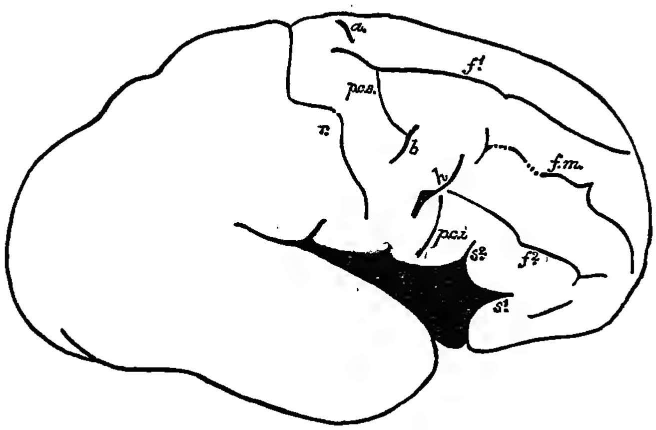


FIG. 60.—Profile view of a cerebrum from a male fœtus in the latter part of the seventh month of development. Drawn by the American apparatus for tracing orthogonal projections of the skull. The dotted lines indicate the position of the deep bridging gyri.

r. . . . Fissure of Rolando.
p. c. s. . . Sulcus præcentralis superior.
a. . . . Sulcus præcentralis marginalis.
h. . . Horizontal limb of the sulcus præcentralis inferior.
p. c. i. . . Vertical limb of the sulcus præcentralis inferior.
*s.*² . . . Ascending anterior limb of Sylvian fissure.
*s*¹. . . . Anterior horizontal limb of Sylvian fissure.
*f.*¹ . . . Sulcus frontalis primus.
f. m. . . Sulcus frontalis medius.
*f.*² . . . Sulcus frontalis secundus.

VIII. **Sulcus Frontalis Mesialis.**—Broca has called attention to the fact, that the convex external surface of the superior frontal convolution is never simple. "It is always more or less subdivided by furrows directed

principally in the anterior-posterior direction, but often terminating at their posterior extremities by a more or less transverse branch (incisure en T ou en L). In the most ordinary type there are three distinct longitudinal furrows." He then goes on to say that two of these may unite so as to subdivide the superior frontal convolution into two tiers.* It was the presence of these sulci that led Benedikt† to believe that the two uppermost "Urwindungen" of the carnivore brain were in man fused into one, and represented by the superior frontal convolution.

These sulci are present in a more or less prominent fashion in all European brains, and as they effect a partial subdivision of the first frontal convolution into a mesial and an external portion, I purpose grouping them under the name of sulcus frontalis mesialis. Associated with them, and lying in direct series with them, we note the sulcus præcentralis marginalis to which we have already alluded (p. 258).

There is not a trace of the sulcus frontalis mesialis in the anthropoid apes. It therefore constitutes a group of sulci peculiar to the human brain. Further, it would appear that these furrows are feebly developed or even absent in the negro cerebrum. In three out of seven negro hemispheres I could not detect any sign of the sulcus frontalis mesialis; whilst in one only did it attain a development at all comparable with that usually observed in the European.

But it is by no means uncommon to find the different factors of the sulcus frontalis mesialis running into each other so as to produce a long continuous furrow completely dividing the superior frontal convolution into two tiers (*vide* figs. 57 and 59, pp. 259 and 262). When this is the case I have noticed that there is a decided tendency for the sulcus frontalis medius to link itself on to the first frontal sulcus. A complete division of the superior frontal convolution is thus usually associated with an imperfect subdivision of the middle frontal convolution, and *vice versâ*. This is well seen in the two figures referred to. In short, all the evidence goes to prove that the sulcus frontalis medius, with the sulcus frontalis mesialis,

* Description élémentaire des circonvolutions cérébrales de l'homme.—Mémoires sur le cerveau de l'homme et des primates, par Paul Broca, publiés par le Docteur S. Pozzi. Paris, p. 788.

† Anatomische studien an Verbrecher Gehirnen. Epilogomena III., p. 133. Wien, 1879.

are furrows which are not stamped upon the surface of the frontal lobe so firmly as the first and second frontal sulci. They are both furrows with a short phylogenetic history. The middle frontal furrow is first met with in the anthropoid apes; the sulcus frontalis mesialis is only seen in man, and, apparently, it is more strongly marked in high than in low types of brain.

IX. **Development of the Frontal Sulci.**—There is no part of the cerebral surface on which the development of the sulci is so variable as the outer aspect of the frontal lobe. This is not only noticeable in regard to the time and relative order in which the various sulci appear, but also in their mode of development. Consequently, it is extremely difficult to arrive at definite conclusions upon many points of essential importance. Gratiolet fell into the error of supposing that the early appearance of the frontal furrows was a human peculiarity. This was a very natural mistake to make, because it is by no means unusual to meet with fœtal hemispheres in which the frontal part is furrowed, whilst all the rest of the outer surface is smooth.

Ecker* has evidently mistaken the horizontal part of the inferior præcentral furrow for the second frontal sulcus, and, consequently, he is in considerable doubt as to what he should make of the true sulcus frontalis secundus when it exists in a distinct form on the same hemisphere. An inspection of his figure 2, Plate III., makes this manifest. The true inferior frontal sulcus he marks *f.** The same may be seen in his figure 3, Plate IV., which represents the cerebral hemisphere of a ninth-month fœtus. In this the sulcus frontalis secundus is in two pieces, viz. one attached to the vertical stem of the inferior præcentral furrow, and the other free, and a short distance in front of the basal part. These have escaped his notice, whilst he has named the horizontal limb of the præcentral furrow the sulcus frontalis secundus. He recognizes, however, the presence, in the fœtal brain, of a sulcus frontalis medius, and figures it (*vide* his

* Zur Entwicklungsgeschichte der Furchen und Windungen der Grosshirn-Hemisphären Archiv fur Anthropologie. Dritter Band, 1869.

figure 3, Pl. iv.), although he gives it no name. Thus, he says: "A more feeble furrow divides the middle frontal convolution into two branches, of which one is united to the first, and the other to the third frontal convolution."

In my study of the developing sulci on the outer surface of the frontal lobe, I have been greatly puzzled to account for the presence of a long deep furrow which is occasionally observed in the fifth-month cerebrum immediately in front of, and parallel to, the coronal sutural line. Its extremities are placed at an equal distance from the mesial border of the hemisphere above, and the open insula below, and, with the exception of the external perpendicular fissure, it is the only sulcus on the outer surface of the hemisphere at this period (Pl. i., fig. 14, also Pl. ii., figs. 8 and 9, *p. c.*). In certain cases its hinder lip is raised above the level of the anterior lip—a character which renders it still more conspicuous (Pl. ii., fig. 9). At first sight it is apt to be mistaken for the fissure of Rolando, but its position and direction are sufficient to show that it cannot be regarded as an early condition of that furrow. It is not so oblique, and, as we have noted, it lies in front of the coronal line. Further, by measurement we can ascertain that its upper end is placed very much further forward on the cerebral surface. Taking the mesial length of the hemisphere as equal to one hundred, the distance of the upper end of this furrow from the frontal point is 39·7, whereas the relative distance of the upper end of the early fissure of Rolando from the frontal point is 52·7 (*vide* p. 176). It holds a position, therefore, and presents a direction which brings it more into association with the inferior præcentral sulcus. At the same time I am not prepared to insist strenuously that it is an early condition of this furrow, because there are many points in connexion with its further history which render it very difficult to come to a decided conclusion on the question.

If the furrow under consideration really is the sulcus præcentralis inferior, it undergoes a retrograde development in the further stages of the growth of the cerebrum. As exhibited in the fifth-month hemispheres alluded to the furrow presents a relative length very much greater than the vertical stem of the inferior præcentral sulcus at any subsequent period in the development of the brain. Such being the case, we must

not lose sight of the possibility that this early furrow may be a transitory precursor of the præcentral sulcus which becomes obliterated before the true furrow makes its appearance. There is one fact, however, which militates against this view, and it is this: it is not a complete fissure, and it would be quite exceptional to find a furrow which was not due to an infolding of the cerebral wall transitory in character.

As a general rule the sulcus præcentralis inferior is seen in hemispheres which have reached a stage of development corresponding to the early part of the sixth month. Figures 12 to 15 (Pl. II.) represent specimens which were obtained from female twins about this period of development. In all of these the inferior præcentral furrow (*p.c.* and *p.c.i.*) is well marked, but whereas in two (figs. 13 and 14) the vertical stem is alone formed, the others show both the vertical and the horizontal portions of the furrow. Indeed, it will be seen that in figure 12 the typical T-shaped form of sulcus has been already attained. A very remarkable point in connexion with this early inferior præcentral sulcus is the high position which it holds on the side of the cerebrum. A subsequent lowering of the level which is occupied by the furrow at this period must take place, and an interesting field for speculation is opened up in the question as to how this is brought about. Possibly, the growth of the fronto-parietal operculum produces a general downward locomotion of the whole cerebral surface above the insula. Such a growth-change would also affect, but to a less extent, the lower piece of the fissure of Rolando, and also, very slightly, the sulcus postcentralis inferior should it happen to be in place (fig. 13, p^1.).

It is a remarkable circumstance that in those cases where the frontal furrows appear at an early date, they present the straight linear form so characteristic of the fissures of lower apes. It is impossible, in these cases, to analyze the different steps of the process of formation. When they come into existence, however, at a later stage they assume, in the first instance, the form of shallow depressions and furrows which ultimately run into each other. In this manner we have an opportunity afforded of determining the mode of origin of the furrows involved. A study, therefore, of hemispheres somewhat advanced in development, but in which the sulcus præcentralis inferior is not fully formed (Pl. II., figs. 17 to

20, *p. c. i.*), is very instructive. Either the horizontal or the vertical portion may appear first. In figure 17 a deep pit marks the spot where the two parts of the fissure would ultimately unite, and from this three exceedingly shallow depressions radiate. In figure 16 the posterior part of the horizontal ramus is alone evident, whilst in figures 19 and 20 the vertical stem is the only part which can be detected. Figure 18 presents an interesting condition of the early inferior præcentral sulcus. There is a tolerably distinct vertical stem, and immediately above this there may be detected a very slight depression which represents the fore-part of the horizontal limb.

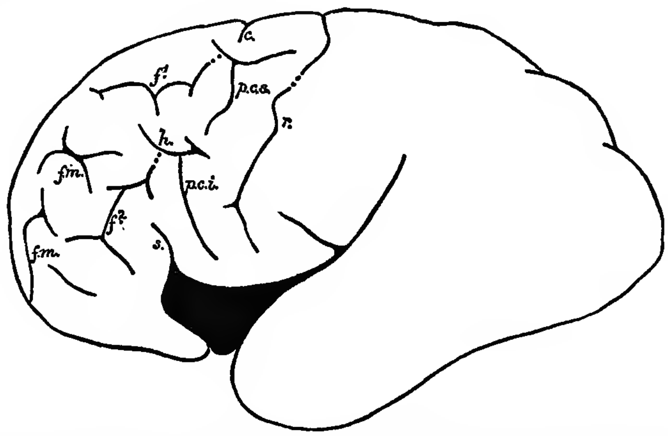


Fig. 61.—Lateral view of the left cerebral hemisphere of a female fœtus in the early part of the eighth month of development. Drawn by the American apparatus for tracing orthogonal projections of the skull. The dotted lines indicate the position of the deep annectant gyri.

r. . . . Fissure of Rolando.
p. c. i. . Sulcus præcentralis inferior.
p. c. s. . Sulcus præcentralis superior.
s. . . . Single anterior limb of Sylvius.
c. . . . Sulcus præcentralis medialis.

*f.*¹ . . Sulcus frontalis primus.
f. m. . Sulcus frontalis medius.
*f.*² . . Sulcus frontalis secundus.
h. . . Horizontal limb of the inferior præcentral sulcus.

It is apparent, therefore, that although in certain cases the sulcus præcentralis inferior may be developed continuously by three furrows radiating in a downward, backward, and forward direction from a central point which corresponds in the adult to the place of union between its vertical and horizontal limbs (Pl. ii., fig. 17), it may also be formed by the fusion of separate pieces which have an independent origin. The vertical

stem is always developed in one piece, but the horizontal limb may arise from the union of a posterior and an anterior depression. We have already noted that in 8·5 per cent. of the adult hemispheres examined, a deep annectant gyrus intervened between the horizontal and vertical parts of the inferior præcentral sulcus, and, further, that in 2·1 per cent. this gyrus was observed on the surface; a deep annectant gyrus was also in rare instances seen at the base of either the anterior or posterior portions of the horizontal ramus. All these conditions are explained by the manner in which the sulcus is developed.

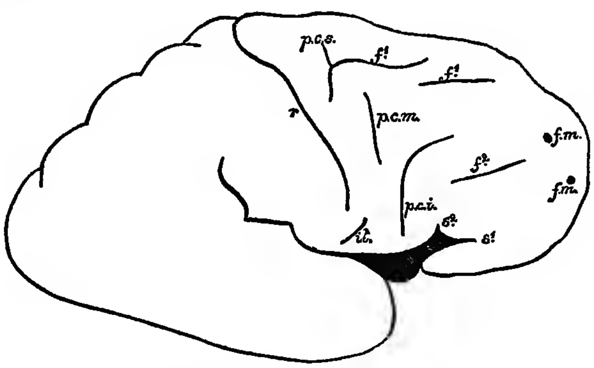


Fig. 62.—Lateral view of the right hemisphere of a fœtus in the latter part of the seventh month of development. Drawn by the American apparatus for tracing orthogonal projections of the skull.

r.	Fissure of Rolando.	*p. c. i.*	Sulcus præcentralis inferior.
p. c. s.	Sulcus præcentralis superior.	*i. t.*	Sulcus transversus of the fissure of Rolando.
f.[1]	Sulcus frontalis superior.	*f.*[2]	Sulcus frontalis inferior.
p. c. m.	Sulcus præcentralis medius.	*f. m.*	Sulcus frontalis medius.

In figure 60, p. 268, a fœtal brain well on in the seventh month of development is represented, in which the horizontal portion of the furrow is still separate from the vertical stem.

We have already mentioned that in the last two or three months of fœtal life, the horizontal limb of the sulcus præcentralis inferior is, as a rule, more evident, and apparently more distinctly sagittal in its direction than in more advanced stages of growth. Figure 61 is a good example of this (*vide* also fig. 54, p. 250; fig. 55, p. 251; Pl. I., fig. 33).

The condition exhibited in the above figure (fig. 62) is interesting.

The upper part of the inferior præcentral sulcus is bent forwards to form the anterior part of the ramus horizontalis, but the posterior part is absent. A well-marked middle præcentral furrow is evident, and in such a position that the idea is suggested that it may possibly represent the detached posterior part of the horizontal ramus of the inferior præcentral sulcus.

The inferior or second frontal sulcus appears simultaneously with, or immediately after, the sulcus præcentralis inferior. As a rule, it becomes evident about the end of the sixth month, although in some cases it may be seen earlier (*vide* Pl. II., fig. 14). It is generally composed, in the first instance, of two pieces, an anterior and a posterior, which ultimately run into each other (Pl. I., fig. 25; and Pl. II., figs. 14 and 20). As we have observed, the point of union of these two pieces is frequently indicated in the adult brain by the presence of a deep annectant gyrus, whilst a failure in their junction leads to the retention of this bridging convolution on the surface. In figure 19 (Pl. II.) it will be noticed that the two portions of the furrow are exhibited in the form of two pit-like depressions, which are united by a shallow furrow over an intervening eminence.

The hinder or basal part of the inferior frontal sulcus may be developed in direct connexion with the sulcus præcentralis inferior, and when this is the case it is often extremely difficult to distinguish it from the ramus horizontalis—more especially in those cases where the latter is poorly developed or not yet formed. As an example of this I may call attention to a cerebrum figured in Plate II. (fig. 24). The strongly-marked sagittal branch which proceeds forwards from the vertical stem of the inferior præcentral sulcus presents a striking similarity to the ramus horizontalis as it is seen in its typical F-shaped form in a lower ape. Notwithstanding this there cannot be a doubt but that it is in reality the basal or hinder part of the second frontal sulcus. The ramus horizontalis in this specimen is very feebly marked. It is represented by a weak bifurcation at the upper extremity of the vertical stem.

Another case which presents similar elements of difficulty is seen in the annexed figure (fig. 63, p. 276). The basal portion of the inferior frontal sulcus is a long oblique furrow, in direct continuity with the vertical

stem of the inferior præcentral sulcus. It is placed above the level of the anterior part of the same furrow, and its relationship to it is thus obscured. The condition of the ramus horizontalis is also misleading. It has its anterior end tilted upwards, so that it almost assumes a vertical direction.

The development of the basal part of the inferior frontal sulcus in continuity with the inferior præcentral furrow explains those cases in the adult in which we have a complete union of the two furrows. When the basal portion of the furrow is formed independently it may either maintain its separate condition, or extend backwards and unite superficially with the inferior præcentral furrow (p. 255).

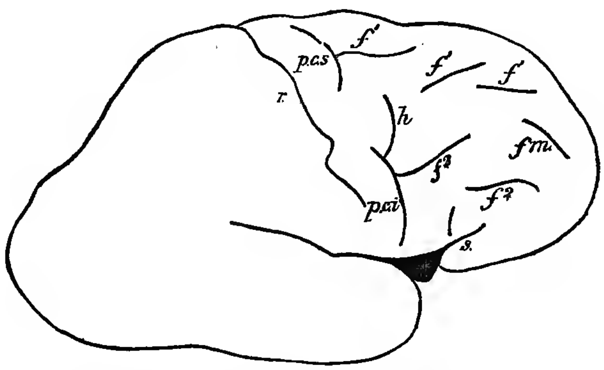


FIG. 63.—Lateral view of a fœtal cerebrum in the latter part of the seventh month of development. Drawn by the American apparatus for tracing orthogonal projections of the skull.

r.	Fissure of Rolando.	*f.*^{2}	Sulcus frontalis inferior.
p. c. s.	Sulcus præcentralis superior.	*f. m.*	Sulcus frontalis medius.
f.^{1}	Sulcus frontalis superior.	*p. c. i.*	Sulcus præcentralis inferior.
h.	Ramus horizontalis.	*s.*^{1}	Single anterior limb of the Sylvian fissure.

But the inferior frontal sulcus does not in every case appear in two separate pieces. Sometimes, from the very first, it assumes the form of a sharply-cut linear furrow (Pl. I., fig. 24, *f.*^{2}).

In figure 31, Plate I., a very puzzling condition is exhibited, and yet it is one which is not very rare. I have lettered the fissure in question *p. c. i.*, although I can hardly believe that it has much in common with the sulcus præcentralis inferior. It seems rather to be an early stage of what is present in the hemispheres figured in pp. 250 and 251. If this be the case

the sulcus under consideration is to be referred to the inferior frontal furrow, and the sulcus præcentralis inferior has not yet appeared.

The terminal bifurcation or transverse piece of the inferior frontal furrow does not come into existence until the middle of the seventh month (fig. 60, p. 268), and often it is later in making its appearance (figs. 54 and 55, pp. 250 and 251). It may be developed separately, or in direct continuity with the main stem of the furrow. The two secondary transverse furrows which lie in front of this (Eberstaller's sulcus radiatus and lateral part of the sulcus fronto-marginalis) are seen for the first time towards the end of the eighth month or the beginning of the ninth month (fig. 33, Pl. i.).

The sulcus frontalis superior and the sulcus præcentralis superior appear in the early part of the seventh month. It is not unusual, however, to meet with them before this period. Thus, in figure 13, Pl. ii., which represents the cerebral hemisphere of a fœtus in the early part of the sixth month, the sulcus præcentralis superior is already evident (*p. c. s.*), whilst in figures 23, 25, and 26, which are drawings of hemispheres of about the same stage of development, traces of the superior frontal sulcus are apparent.

The first steps in the development of both of these furrows may be studied in figures 17 to 20, Plate ii., and later stages are exhibited in figures 62 and 63, pp. 274 and 276. The sulcus frontalis superior appears in two or three pieces, which are placed one in front of the other. The whole process points in the most unmistakable manner to the extremely close connexion which exists between the sulcus præcentralis superior and the first frontal furrow, and all the conditions which we have noted in the adult can be explained by the different modes of development of these sulci in the fœtal brain. The sulcus præcentralis superior is usually formed in two pieces—an upper and a lower. The basal or hinder part of the frontal sulcus is most commonly developed in direct continuity with the lower piece of the superior præcentral sulcus (fig. 19, Pl. ii., *p. c. s.*). Sometimes, however, it is continuous from the first with the upper part of the sulcus præcentralis superior (Pl. ii., fig. 17, *p. c. s.*). Again, it is not unusual to find the superior præcentral furrow separate in its earliest stages, and then it is the lower part which, as a rule, appears first (Pl. ii., figs. 18 and 20, *p. c. s.*).

Hervé * claims for the sulcus frontalis medius a precedence over the other frontal furrows which it does not deserve. He states that it appears in the sixth month, and asserts that it is "le sillon primitif," which divides "the frontal lobe into two stages, or lobules, previous to its decomposition into convolutions." It is true that in a few instances I have observed the sulcus frontalis medius in the cerebrum of a sixth-month fœtus, and I have figured what seems to me to be four examples of this (Pl. II., figs. 22, 23, 25, and 26), but in each of these cases, with one exception, it is associated with the other frontal sulci. This early development of the sulcus medius is quite exceptional. As a general rule it does not appear until about the middle of the seventh month. The anterior sagittal stem is first formed. In figure 63, p. 276, it will be seen as a short continuous furrow ; but in figure 62, p. 274, it is merely represented by two pit-like depressions. Its two posterior parts come into existence later, and may either remain distinct as two separate transverse furrows, or establish a superficial connexion with each other and the main stem (fig. 54, p. 250, and fig. 60, p. 268).

Traces of the fronto-marginal sulcus, or in other words of the terminal cross-piece of the sulcus frontalis medius, are sometimes seen before the main portion of the furrow makes its appearance. This is not common. Often it is developed simultaneously with, but apart from, the sagittal stem. Another mode of formation is that in which the termination of the sagittal stem turns inwards to form the inner piece of the transverse furrow, whilst the outer portion is developed as an independent depression, which ultimately joins its fellow. The reverse condition may also be met with, but much more rarely.

In a few cases the series of shallow furrows which we have grouped under the name of sulcus frontalis mesialis may be seen in the brain of the full-time fœtus. As a rule, however, they do not appear until the first month after birth.

Although the variability which is exhibited by the development of the frontal sulci is so great that it is necessary to proceed with the greatest caution in deducing any general laws from the process, I believe that we

* La circonvolution de Broca, p. 84.

are warranted in asserting that on an average the furrows in question appear in the following order:—

1. The sulcus præcentralis inferior.
2. The inferior frontal furrow.
3. The lower piece of the sulcus præcentralis superior, with the basal part of the superior frontal furrow.
4. The anterior part or parts of the superior frontal furrow, and the upper portion of the sulcus præcentralis superior.
5. The sulcus frontalis medius.
6. The sulcus frontalis mesialis.

X. **Frontal Furrows in the Apes.**—The most striking peculiarity in the frontal lobe of the apes consists in the total absence of the frontal and orbital opercula of the Sylvian region, and the consequent exposure on the surface of a portion of the insula. This interpretation of the condition present is strenuously denied by the great majority of anatomists, but a prolonged study of the region has only served to convince me the more fully that it is the case. But further, the most conflicting opinions are entertained regarding the homologies of the various furrows on the outer surface of the lobe. More particularly has the inferior frontal furrow been a source of difficulty. The discovery by Broca of the motor centre for speech in the basal part of the inferior frontal convolution has, undoubtedly, had the effect of leading many observers to rashly conclude that this convolution is either entirely absent, or only very poorly represented in the apes. In man, however, as we shall see, the inferior frontal convolution usually consists of an opercular and an extremely small non-opercular part. The former, it is true, is almost entirely absent in the apes; but the non-opercular part, which is placed above the level of the insula, is undoubtedly present. From this it will be seen that I believe in the truth of Gratiolet's views, in regard to the homologies of the inferior frontal furrow in the apes, although at the present day it may almost be said that these have been universally discarded.

In order that I may be able to develop this branch of the subject, it will be necessary to study in detail the frontal furrows as they are exhibited in certain of the lower apes, and from them to advance

upwards to the conditions present in the cerebrum of the anthropoids and man.

Let us begin with Cebus (fig. 64). The outer aspect of the frontal lobe exhibits an exceedingly simple surface pattern. There are only two fissures. Of these one presents a T-shaped figure, and is composed of a lower vertical (*p. c. i.*) and an upper horizontal limb (*h.*). The latter has the appearance of a terminal bifurcation of the former, and therefore it consists of an anterior and a posterior branch. In the early human fœtal brain the inferior præcentral sulcus sometimes presents a figure precisely

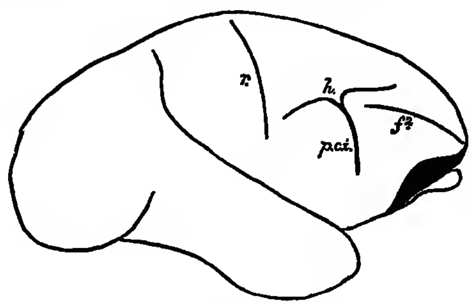


FIG. 64.—The outer surface of the cerebrum of *Cebus albifrons*. Drawn by the American instrument for tracing orthogonal projections of the skull. *r.*, fissure of Rolando; *p. c. i.*, sulcus præcentralis inferior; *h.*, ramus horizontalis; $f.^2$, inferior frontal sulcus.

similar to this (*vide* fig. 12, *p. c. i.*, Pl. II.). The second furrow is a straight clean cut fissure ($f.^2$), which begins behind in the angle between the anterior branch of the horizontal limb and the vertical limb of the T-shaped fissure, but it never in the lower apes communicates with either. It is important to note particularly its position below the level of the horizontal limb of the T-shaped fissure. From this it extends forwards to the pointed frontal pole. It is called by Eberstaller the sulcus rectus;* and this name we shall apply to it until we establish its proper homology.

The next form which we shall examine is Callithrix (fig. 65). In this the arrangement is slightly different. The posterior branch of the horizontal limb of the T-shaped sulcus of Cebus is wanting. The furrow consequently presents an F-shaped figure. This form of the fissure

* Das Stirnhirn, p. 112. Leipzig, 1890.

is also met with in the human fœtus (*vide* Pl. ii., fig. 15, *p. c.*). Seeing, therefore, that the furrow under consideration may exhibit a different appearance in different forms, we may distinguish it by the provisional name of sulcus arcuatus (first applied to it by Mingazzini*) until we are in a position to give to it a name which will indicate its homology.

The sulcus rectus ($f.^2$) presents the same appearance and relations as the corresponding furrow in Cebus. In Callithrix, however, we have two additional sulci. These are exceedingly shallow and short furrows. The one is placed in front of the lower part of the vertical limb of the sulcus arcuatus and immediately above the superciliary margin of the frontal lobe.

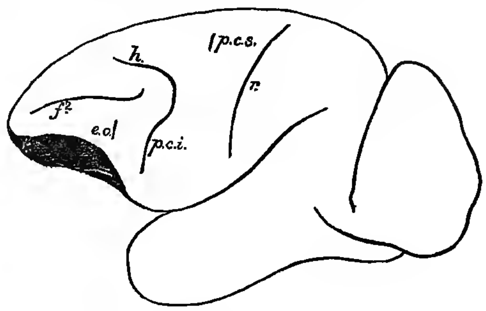


Fig. 65.—Outer surface of the cerebrum, Callithrix. Drawn by the American apparatus for tracing orthogonal projections of the skull. *r.*, fissure of Rolando; *p. c. i.*, sulcus præcentralis inferior; $f.^2$, sulcus frontalis inferior; *p. c. s.*, sulcus præcentralis superior (?); *e. o.*, a slight trace of the sulcus fronto-orbitalis.

It is a feeble representative of the sulcus fronto-orbitalis of Waldeyer† or the sulcus orbito-frontalis of Broca. The second little furrow is situated above the level of the sulcus arcuatus and is in all probability a feeble representative of the sulcus præcentralis superior or of the basal part of the first frontal sulcus.

The cerebrum of the baboon (fig. 66) brings us a step nearer to the condition which is found in the brain of the anthropoid apes. The sulcus arcuatus (*p. c. i.*) is easily recognized. It exhibits the T-shaped form, but

* Intorno ai solchi e le circonvoluzioni cerebrali dei primati et del feto umano. Estratto dagli Atti della R. Accademia Med. di Roma. 1888. Vol. iv., serie ii.

† Das Gibbon-Hirn. Internationale Beiträge zur Wissenschaftlichen Medicin. Festschrift, Rudolf Virchow gewidmet zur Vollendung seines 70. Lebensjahres. Band 1, p. 26.

the hinder branch of its horizontal limb is not so strongly marked as it is in Cebus, and it lies more in a line with the vertical stem of the sulcus. The sulcus rectus ($f.^2$) presents the usual form, and the sulcus fronto-orbitalis has gained in strength and usually turns round the superciliary margin so as to reach the orbital face of the frontal lobe (*e. o.*).

The sulcus præcentralis superior is also more distinctly marked, but its direction is somewhat oblique, and in consequence its identity is obscured (*p. c. s.*). In front of this are two transverse furrows which represent the

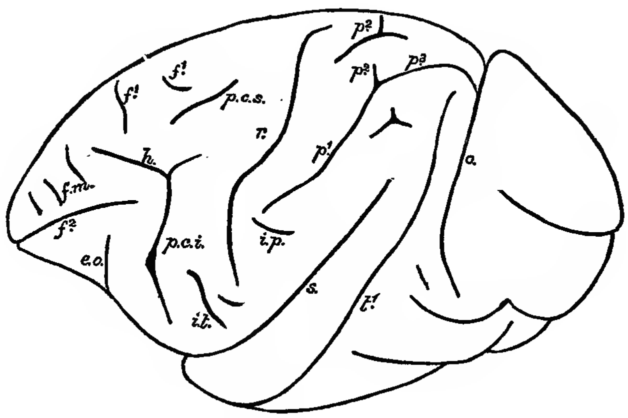


FIG. 66.—The cerebrum of a Chacma Baboon. Drawn by the American apparatus for tracing orthogonal projections of the skull. The upper margin is tilted upwards.

r.	Fissure of Rolando.	$p.^1$	Sulcus postcentralis inferior.
p. c. s.	Sulcus præcentralis superior (?).	$p.^2$	Sulcus postcentralis superior.
p. c. i.	Sulcus præcentralis inferior.	$p.^3$	Sulcus horizontalis intraparietalis.
h.	Horizontal ramus.	*i. p.*	Inferior transverse furrow of the intra-parietal sulcus.
e. o.	Sulcus fronto-orbitalis.	*s.*	Fissure of Sylvius.
$f.^1$	Sulcus frontalis superior.	$t.^1$	Parallel sulcus.
f. m.	Sulcus frontalis medius (?).	*o.*	Anterior lip of the occipital operculum.
$f.^2$	Sulcus frontalis inferior.		
i. t.	Sulcus transversus inferior of the fissure of Rolando.		

early condition of a superior frontal sulcus. Three short transverse furrows placed in front of these, but at a lower level and more directly in the line of the horizontal limb of the sulcus arcuatus, may represent the first indication of the sulcus frontalis medius (*f. m.*).

The various anatomists who have studied the sulci on the outer surface of the frontal lobe have arrived at very different conclusions regarding their homologies. Eberstaller* and Waldeyer† have both given a very complete and exact account of these diverse opinions on this question, so that it is merely necessary for me to allude very briefly to them.

According to Gratiolet and those who agree with him the sulcus rectus is the representative in the apes of the sulcus frontalis secundus in man, whilst the horizontal ramus of the arcuate sulcus is the sulcus frontalis primus. On the outer surface of the frontal lobe of the apes according to this theory, therefore, we have the same three tiers of convolutions which are usually recognized in the brain of man, viz.—(1) a superior frontal convolution between the mesial margin of the hemisphere and the horizontal part of the sulcus arcuatus; (2) a middle frontal convolution between the horizontal limb of the arcuate sulcus and the sulcus rectus; and (3) an inferior frontal convolution below the sulcus rectus.‡

Pansch§ argued differently. The sulcus arcuatus he regarded as the representative of the "ersten radiären Primärfurche," which, according to his view, is a compound furrow composed of the inferior præcentral and the second frontal sulci. He further believed that the sulcus rectus is a furrow peculiar to the apes and completely absent in the human brain.

We now come to those authors who consider that the inferior frontal convolution in the apes is either absent or extremely feebly developed. Thus Bischoff‖ regards the vertical limb of the sulcus arcuatus as the sulcus præcentralis superior, and its horizontal limb as the sulcus frontalis primus. The sulcus rectus, according to this author, is certainly not the

* Das Stirnhirn, p. 113. Leipzig, 1890.

† Das Gibbon-Hirn. Internationale Beiträge zur Wissenschaftlichen Medicin. Virchow's Festschrift. Band I., p. 35.

‡ Mémoire sur les plis cérébraux de l'homme et des primates. Paris, 1854.

§ Ueber die typische Anordnung der Furchen und Windungen auf den Grosshirn-Hemisphären des Menschen und der Affen. Archiv für Anthrop. Band III., 1869.

‖ Die dritte oder untere Stirnwindung und die innere obere Scheitelbogenwindung des Gorilla. Morph. Jahr. Band VII., 1882.

inferior frontal furrow, but merely a fissure dividing the middle convolution into an upper and a lower part.*

Schwalbe† and Mingazzini‡ divide the outer surface of the frontal lobe into an upper and a lower area by the horizontal limb of the sulcus arcuatus and the sulcus rectus, both of which together, in their opinion, represent the sulcus frontalis primus in man.

The most recent hypothesis which has been put forward on this question is that which has been elaborated by Eberstaller § and Hervé.|| I shall not attempt to go into the question of priority. Waldeyer¶ has stated the case briefly and very fairly. I shall merely say that the theory, as it is represented to us by Eberstaller, is one which has been worked out with the greatest care, and rests upon a very different basis from same hypothesis as it is presented to us by Hervé. Waldeyer remarks: "Die Feststellung dieser Homologie gebührt, so weit ich sehe, vor Allem Eberstaller." I would endorse this statement if I were able to accept the hypothesis. Both authors virtually arrive at the same conclusions. These, as expressed by Eberstaller, may be stated briefly thus:—

1. The sulcus rectus represents the sulcus frontalis medius in man.

2. The sulcus arcuatus is the homologue of the sulcus præcentralis inferior in man.

3. In many of the lower apes the sulcus frontalis primus is present in the form of two or three shallow furrows which are placed between the horizontal part of the sulcus arcuatus and the mesial border of the hemisphere. The hindermost of these, if transverse in its direction, may represent a sulcus præcentralis superior.

* It may be well to mention that Bischoff did not always hold these views. In his earlier and greater work ("Die Grosshirn-Windungen des Menschen," Abh. d. 2. Cl. d. k. Akad. der Wiss., x. Band, 2. Abth., p. 460), he expresses himself very differently.

† Lehrbuch der Neurologie. Erlangen, 1881.

‡ Intorno ai solchi le circonvoluzioni cerebrali dei primati et del feto umano. Estratto dagli Atti della R. Accad. Med. di Roma, 1888, vol. iv., serie ii.

§ Das Stirnhirn. Leipzig, 1890.

|| La circonvolution de Broca. Paris, 1888.

¶ Das Gibbon-Hirn. Internationale Beiträge zur Wissenschaftlichen Medicin. Virchow's Festschrift, Band i., p. 35.

4. The sulcus fronto-orbitalis is the homologue of the sulcus frontalis secundus in the human brain. It follows from this that, as the sulcus fronto-orbitalis is only developed in a few of the lower apes and in the anthropoids, the sulcus frontalis inferior, according to Eberstaller, is absent in the majority of the lower apes.

I fully agree with Eberstaller in the views which he has expressed regarding the sulcus arcuatus, the sulcus frontalis primus, and the sulcus præcentralis superior, but I cannot accept the theory he has advanced upon the homologies of the sulcus rectus, the sulcus frontalis medius, and the sulcus fronto-orbitalis, although I recognize and appreciate the plausibility and force of the various arguments which he has adduced in favour of his contention.

The constancy of the sulcus arcuatus in the lower apes, and the early appearance in the human fœtus of a furrow similar in form and similar in position, afford us both phylogenetic and ontogenetic evidence in favour of the view that it is the sulcus præcentralis inferior. In the human cerebrum the sagittal limb of this furrow, as we have noted, may undergo considerable modification. In many cases, however, it retains its early, primitive, and typical form (fig. 53, p. 248).

The first frontal furrow is one of late phylogenetic origin. In several of the lower apes it is totally absent, and even in its highest state of development it is only represented by two or three oblique or transverse shallow furrows which are quite distinct from each other (see the sketch of the baboon's cerebrum, fig. 66). This permanent condition in the lower apes is fully in accord with the transitory conditions exhibited in the development of the furrow in the human cerebrum. In man it is relatively late in making its appearance on the surface of the frontal lobe, and it always comes into existence in the first instance in the form of a series of isolated furrows, which, as a rule, run together, although it is not uncommon, especially in the negro, to find them remaining separate.

The close association which exists between the basal part of the first frontal furrow and the superior præcentral sulcus renders it extremely difficult to say at what point in the ape-series the latter sulcus makes its appearance. It is unmistakably present in the chimpanzee and in the

orang; and Kohlbrügge * states that it occurs amongst the lower apes only in one form, viz. in *Cynocephalus porcarius.* In both Callithrix and the chacma baboon there seems to be a tendency to its formation; but I am not prepared to insist that in these cases the furrow which I have marked *p. c. s.* is the representative of the sulcus præcentralis superior (fig. 65, p. 281, and fig. 66, p. 282); and perhaps in marking the furrow *p. c. s.* in the drawings alluded to, my judgment has been somewhat biassed by the fact that in the human fœtal brain the furrow in question appears to be more firmly established than the sulcus frontalis superior.

The sulcus rectus in the lower apes I believe to be the same as the sulcus frontalis inferior in man. In this respect my views are in accordance with those which were first expressed by Gratiolet. I see no reason for adopting the opinion advanced by Eberstaller and Hervé, that in the human brain it is the homologue of the sulcus frontalis medius.

Speaking of this furrow, Eberstaller says: "Die untere Stirnfurche des Menschen ist er nicht, denn 1. ist die untere Stirnfurche des menschlichen Hirns nicht gegen den Stirnpol ziehend, und 2. kann das Oberflächengebiet, welches zwischen ihm und der Orbitalkante liegt, nicht als 3. Stirnwindung gelten, denn diese schlägt sich, wie Bischoff ganz richtig argumentirte, um die vordere Ecke der Sylvischen Grube herum. Was aber dann?"

I must confess that neither of these arguments appeal to me with any force. The direction of the furrow in the brain of the low apes and in the brain of man is undoubtedly different; but consider the difference of form of the frontal lobe in the two cases. In the apes the frontal region is narrow and pointed, and the superciliary margin is pushed high upwards by the elevated convex orbital plate of the frontal bone. In man the outer surface of the lobe has gained in breadth, and the superciliary margin has descended. In what direction has the growth which has produced the massive frontal lobe of man proceeded? Certainly not in an upward direction. Everything points to a general outward and downward growth, and this affords us some explanation as to the change in the

* "Versuch einer Anatomie des Genus Hylobates." Zoologische Ergebnisse einer Reise in Niederländisch Ost-Indien. Band II., p. 188. Leiden, 1891.

direction of the furrow in the human brain. But whether this explanation is right or wrong, I do not consider that much weight should be ascribed to a slight difference of inclination in the determination of so important a homological question. I may further add that in many cases the inferior frontal furrow, in its early stages of development in the human cerebrum, presents a direction similar to that of the sulcus rectus in the lower apes (fig. 62, p. 274). Indeed the general tendency of the frontal furrows, both in the apes and in the early stages of their existence in the human fœtus, is to assume an oblique and not an accurately sagittal direction. We see this not only in the sulcus rectus or inferior frontal furrow, but also in the several pieces which go to form the first frontal sulcus—all tend by their anterior ends somewhat towards the mesial border.

With regard to the second argument advanced by Eberstaller, I may as well at once state that my views regarding the "anterior angle of the Sylvian region," and the so-called anterior limb of the Sylvian fissure in the apes, are altogether different from those which are usually accepted, and are more in accordance with those which have been advocated by Pansch and Kohlbrügge. At a later stage I hope to be able to establish my position in this respect. If I do so, Eberstaller's contention falls to the ground.

The evidence in favour of regarding the sulcus rectus in the cerebrum of the lower apes the homologue of the sulcus frontalis inferior in the cerebrum of man is derived from the following circumstances:—

1. The position of the sulcus in relation to the sulcus arcuatus or inferior præcentral furrow in the apes and in man.

2. Its early development in the human cerebrum.

3. The presence in many cases in the cerebrum of the chimpanzee of a true sulcus frontalis medius, in addition to the sulcus rectus or inferior frontal sulcus.

In the brain of the lower apes, one of the most conspicuous features of the sulcus rectus is the position of its hinder end below the level of the horizontal limb, and close to the vertical stem of the sulcus præcentralis iuferior (*vide* the sketches of the cerebrum of Cebus, Callithrix, and the chacma baboon, figs. 64, 65, 66, pp. 280–282). In the human cerebrum, when the

furrows are disposed in a simple manner, the hinder end of the inferior frontal sulcus presents precisely the same relations. To show this, I introduce a sketch of the fissures on the outer surface of the frontal lobe of a female brain. Not only is the hinder end of the inferior frontal sulcus seen to be placed below the sagittal part of the inferior præcentral

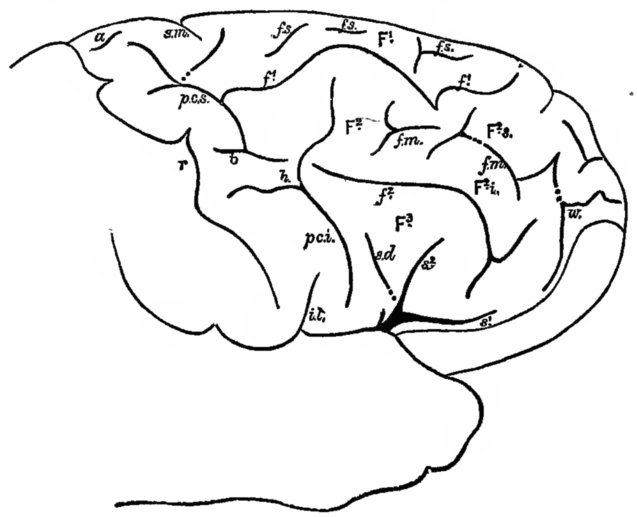


FIG. 67.—Right cerebral hemisphere of an adult female. Drawn by the American apparatus for tracing orthogonal projections of the skull. The dotted lines indicate the position of the deep annectant gyri.

r. . . . Fissure of Rolando.
a. . . . Sulcus præcentralis marginalis.
s m. . Sulcus præcentralis medialis (of Eberstaller).
p. c. s. Sulcus præcentralis superior.
p. c. i. . Sulcus præcentralis inferior (vertical stem).
h. . . . Horizontal ramus of the sulcus præcentralis inferior.
f. s. . . Sulcus frontalis mesialis.
*f.*¹ . . Sulcus frontalis superior vel primus.
f. m. . Sulcus frontalis medius.
*f.*² . . Sulcus frontalis inferior vel secundus (the sulcus rectus of the low apes).
*F.*¹ . . Gyrus frontalis superior.
*F.*² *s.* . Upper part of the gyrus frontalis medius.
*F.*² *i.* . Lower part of the gyrus frontalis medius.
*F.*³ . . Gyrus frontalis inferior.
w. . . Sulcus fronto-marginalis of Wernicke.
s. d. . . Sulcus diagonalis of Eberstaller.
*s*¹. . . Anterior horizontal Sylvian limb.
*s.*². . . Anterior ascending Sylvian limb.
i. t. . . Inferior trausverse furrow of the fissure of Rolando (Eberstaller).

sulcus, but it will be observed that the sulcus frontalis medius lies more or less directly in the line of the sagittal portion of the inferior præcentral furrow. In the excellent drawing which is given by Eberstaller of a left human cerebral hemisphere (Das Stirnhirn, p. 117, fig. 9), these relations are

exhibited even more distinctly. Further, in many of the figures which I have introduced for the purpose of illustrating the arrangement of the frontal furrows (fig. 55, p. 251, and fig. 60, p. 268), the same conditions are depicted. When the sagittal part of the inferior præcentral furrow is typically developed in the human cerebrum it is therefore evident: (1) that the hinder end of the inferior frontal sulcus presents the same relations to it that the sulcus rectus presents to the sulcus arcuatus (sulcus præcentralis inferior) in the lower apes; and (2) that the sulcus frontalis medius of the human cerebrum lies more or less directly in the line of the sagittal part of the inferior præcentral sulcus. These relations are sufficient of themselves to cause us to regard Eberstaller's assertion that the sulcus rectus of the ape and sulcus frontalis medius of man are identical furrows, with grave distrust.

But, as I have said, the phylogenetic and ontogenetic evidence also points in a similar direction. The sulcus rectus shares with the sulcus præcentralis inferior an equal pre-eminence in the ape-cerebrum. It would be difficult to say which presented the greater value from the morphological point of view. They are both present (so far as I am aware) in the brains of the great majority of the lower apes, and they exhibit a very nearly equal depth. Turning now to the human fœtal cerebrum, we recognize the same pre-eminence in so far as their development is concerned. It is true that the inferior præcentral sulcus usually takes the lead, but it is followed very closely by the inferior frontal furrow, and it is only in exceptional cases that the sulcus frontalis medius appears before it.

The proof that is afforded by the chimpanzee cerebrum is still more convincing. Eberstaller is perfectly right when he remarks that there are great variations to be noticed in the arrangement of the frontal furrows in different chimpanzee brains. One of the leading differences consists in the presence or the absence of the sulcus frontalis medius. It is only in the anthropoid brain that this sulcus first assumes a definite form. It is true that in the cerebrum of the chacma baboon there are two small transverse furrows developed in front of the sagittal limb of the inferior præcentral sulcus (fig. 66, p. 282, *f. m.*), which may represent the first traces of this sulcus in the apes, but upon this point I am by no means sure.

To my mind the occasional association of a distinct sulcus frontalis medius in the chimpanzee brain, in all respects similar to the corresponding furrow in the human cerebrum, with an inferior frontal furrow (sulcus rectus) altogether distinct from the sulcus fronto-orbitalis, is proof

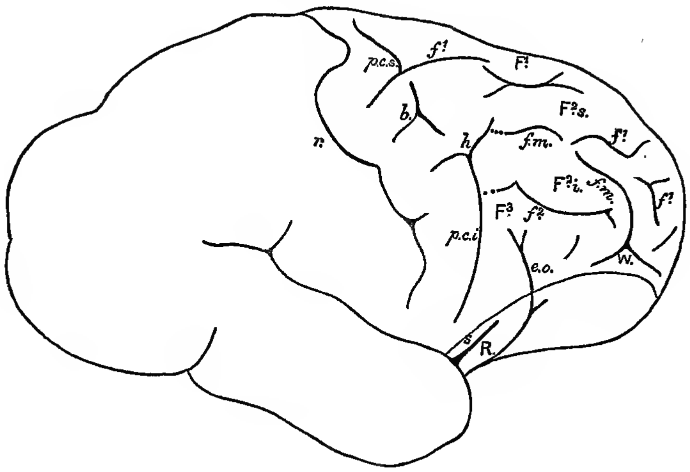


Fig. 68.—Right cerebral hemisphere of a young chimpanzee (probably about three years old). Drawn by the American apparatus for tracing orthogonal projections of the skull. The dotted lines indicate the position of the deep annectant gyri.

r.	Fissure of Rolando.	*f.*¹	Sulcus frontalis superior.
p. c. s.	Sulcus præcentralis superior.	*f. m.*	Sulcus frontalis medius.
b.	Probably the lower part of the sulcus præcentralis superior, detached from the upper part. If it were joined, the cruciform arrangement of the præcentral sulcus and the basal part of the sulcus frontalis superior would be exhibited.	*w.*	Sulcus fronto-marginalis of Wernicke.
		*f.*²	Sulcus frontalis inferior (sulcus rectus).
		e. o.	Sulcus fronto-orbitalis.
		s.	Anterior free border of the fronto-parietal operculum—the so-called anterior limb of the Sylvian fissure of most authors.
		R.	Exposed part of the insula.
p. c. i.	Vertical stem of the sulcus præcentralis inferior.	*F.*¹	Gyrus frontalis superior.
		*F.*² *s.*	Upper part of gyrus frontalis medius.
h.	Horizontal ramus of the inferior præcentral furrow.	*F.*² *i.*	Lower part of gyrus frontalis medius.
		*F.*³	Gyrus frontalis inferior.

positive that the sulcus rectus in the apes does not represent the sulcus frontalis medius in man. I shall now give two drawings obtained from the right and left cerebral hemispheres of a young female chimpanzee, in which this condition is well seen.

In the right hemisphere of this cerebrum (fig. 68) the sulcus frontalis superior is in four separate and distinct pieces, which are placed one in front of the other, a short distance from the mesial border. It therefore presents in permanent form what is usually a transitory condition of the corresponding furrow in the human fœtus. It will be noticed, further, that these distinct pieces of the furrow are oblique, and incline by their anterior ends towards the mesial border of the hemisphere—the hinder extremity of each lying at a lower level than the anterior extremity of the one immediately preceding it. In those cases in the human cerebrum where the constituent parts of the superior frontal furrow remain separate, we have likewise observed this arrangement to be a characteristic feature.

A well-marked sulcus præcentralis superior is present in connexion with the basal or hinder part of the superior frontal furrow. The appearance is such, however, that I am inclined to consider that the upper part of the superior præcentral furrow (*p. c. s.*) alone is joined to the superior frontal sulcus, and that the lower part is in reality the hinder end of the frontal sulcus carried backwards towards the fissure of Rolando. If this be the case, the lower part of the sulcus præcentralis superior is represented by the furrow immediately below (*b.*).

The inferior præcentral sulcus is well developed. It consists of a long, vertical stem (*p. c. i.*), surmounted by a short horizontal ramus (*h.*).

The sulcus frontalis medius is in two portions (*f. m.*). The posterior part is a short, straight furrow, which runs in the sagittal direction, and is connected behind with the front branch of the ramus horizontalis of the sulcus præcentralis inferior. A very distinct deep annectant gyrus, which is indicated in the drawing by a dotted line, marks the point of junction. The front part of the sulcus frontalis medius is in every respect similar to the corresponding part of the furrow in the human cerebrum. It is sagittal in its direction, and traverses the anterior half of the middle frontal gyrus. Towards its extremity it curves slightly downwards, and finally ends at the superciliary margin by bifurcating into two widely spread-out limbs, which together form a typical fronto-marginal sulcus of Wernicke (*w.*). Throughout the whole course of this furrow there is not the slightest indication of a deep annectant gyrus.

The sulcus frontalis inferior (sulcus rectus) ($f.^2$) extends forwards above the upper end of the sulcus fronto-orbitalis (*e. o.*). It pursues a straight course, and shows no tendency to bend in a downward direction towards its anterior end. In short, it is directed towards the frontal pole. Its hinder end is joined to the vertical stem of the inferior præcentral sulcus, but the communication is interrupted by the presence of a distinct deep gyrus.

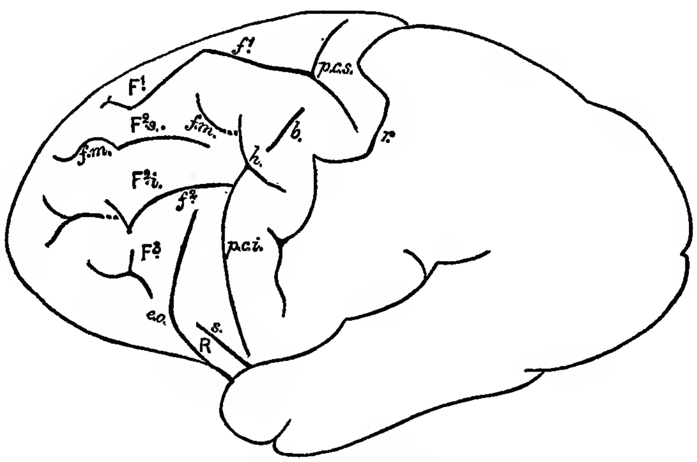


FIG. 69.—Left hemisphere of a young female chimpanzee, probably about three years old. Drawn by the apparatus for tracing orthogonal projections of the skull. The dotted lines indicate the deep annectant gyri.

r.	Fissure of Rolando.	*e. o.*	Sulcus fronto-orbitalis.
p. c. s.	Sulcus præcentralis superior.	$f.^1$	Sulcus frontalis superior.
b.	Lower limb of sulcus præcentralis superior (?).	*f. m.*	Sulcus frontalis medius.
p. c. i.	Sulcus præcentralis inferior.	$f.^2$	Sulcus frontalis inferior.
h.	Ramus horizontalis.	$F.^1$	Gyrus frontalis superior.
s.	Anterior free border of the fronto-parietal operculum — the so-called anterior Sylvian limb.	$F.^2$ *s.*	Superior part of gyrus superior medius.
		$F.^2$ *i.*	Inferior part of gyrus superior medius.
		$F.^3$	Gyrus frontalis inferior.
R.	Exposed part of the insula.		

In the left hemisphere (fig. 69) the arrangement of the furrows is not so distinct, seeing that several of them have entered into abnormal connexions with their neighbours; still with the right hemisphere as a guide the interpretation of the conditions present is not difficult.

The sulcus frontalis superior (*f.*[1]) is present in the form of a long continuous furrow, free from interrupting deep annectant gyri. The præcentralis superior (*p. c. s.*) is well marked; but, as in the case of the right hemisphere, it is difficult to decide whether the furrow lettered "*b*" is the lower piece of this sulcus, or a sulcus præcentralis medius.

The sulcus præcentralis inferior (*p. c. i.*) is very similar to the corresponding furrow in the opposite hemisphere, but the ramus horizontalis (*h*) is, if anything, more obliquely placed.

The sulcus frontalis medius (*f. m.*) is broken up into three pieces. The hindermost of these is superficially connected (as in the right hemisphere) with the front limb of the ramus horizontalis of the inferior præcentral sulcus. The second or intermediate piece takes an oblique course towards the mesial border. It is a clean-cut deep furrow; and I am inclined to believe that anteriorly it has entered into connexion with and completely absorbed a detached part of the sulcus frontalis superior. It is right to state, however, that there is no deep annectant gyrus present to mark the point of junction. The terminal piece thus forsaken by the intermediate part has entered into an abnormal connexion with the inferior frontal sulcus. At least that is the light in which I am inclined to regard the bifurcated furrow which lies front of the inferior frontal sulcus. A high, deep annectant gyrus indicates the point of union.

The inferior frontal sulcus (*f.*[2]) is arranged in the same manner as the corresponding furrow on the opposite hemisphere, with two exceptions: (1) it enters into complete union behind with the vertical stem of the inferior præcentral sulcus; (2) it presents, as we have noted, an abnormal but superficial connexion in front with what appears to be the terminal part of the sulcus frontalis medius.

A third chimpanzee hemisphere in my possession exhibits an arrangement of the furrows on the frontal lobe very similar to that just described. The sulcus frontalis medius, however, is more distinct, and its terminal part is not connected with the inferior frontal sulcus. All the sagittal furrows are more or less oblique, and tend towards the mesial border by their anterior extremities.

In a fourth chimpanzee hemisphere I can see no trace of a sulcus

frontalis medius. The inferior frontal furrow (sulcus rectus), with its hinder end placed below the horizontal part of the ramus horizontalis of the sulcus præcentralis inferior, is very distinct.

In a drawing which is given by Broca * of the outer surface of the cerebrum of a gorilla, there is indicated a very distinct sulcus frontalis medius in conjunction with a sulcus frontalis inferior. The upper part of

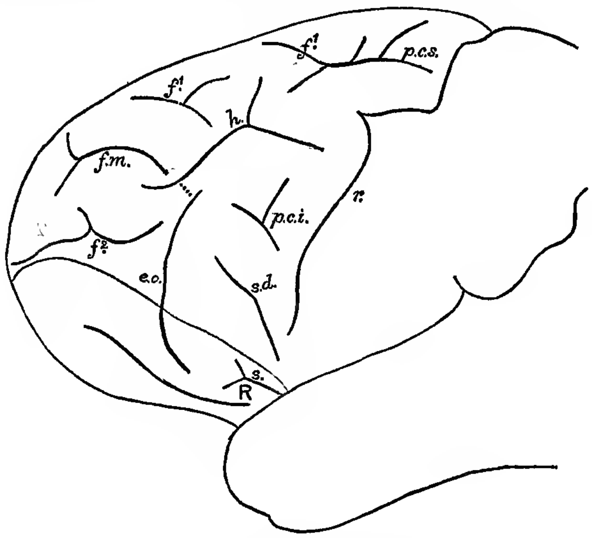


FIG. 70.—Left cerebral hemisphere of an orang. Drawn by the American apparatus for tracing orthogonal projections of the skull.

r. . . . Fissure of Rolando.
i. t. . . . Inferior transverse furrow of the fissure of Rolando (Eberstaller).
p. c. i. . . Sulcus præcentralis inferior.
h. . . . Horizontal ramus of the inferior præcentral sulcus (?).
p. c. s. . . Sulcus præcentralis superior.
*f.*¹ . . . Sulcus frontalis superior.
f. m. . . Sulcus frontalis medius (?).
*f.*² . . . Sulcus frontalis inferior.
e. o. . . . Sulcus fronto-orbitalis.
s. . . . Anterior free border of the fronto-parietal operculum (the so-called anterior limb of the Sylvian fissure).
R. . . . Exposed part of the insula.

the vertical stem of the sulcus præcentralis inferior is bent very much backwards, so that the horizontal ramus is very nearly vertical in its direction. The sulcus frontalis inferior communicates behind with the curved vertical stem of the inferior præcentral sulcus; and from this point

* "Étude sur le cerveau du gorille," Revue l'Anthropologie. 2ᵉ. série, t. I., Pl. 2, fig. 3.

it is carried forwards above the upper end of the sulcus fronto-orbitalis. At a higher level is seen the sulcus frontalis medius; and it will be observed that this ends at the superciliary margin in a well-marked sulcus fronto-marginalis of Wernicke.

Eberstaller's drawings of the chimpanzee cerebrum are not very distinct, but it appears to me that in the left hemisphere which he has figured (Das Stirnhirn; p. 116, fig. 7), the long furrow proceeding forwards from the upper part of the vertical stem of the inferior præcentral sulcus is the representative of the sulcus frontalis medius. I am confirmed in this opinion by his remark that it "is traversed by deep bridging gyri."

The arrangement of the frontal furrows of the orang is extremely puzzling. It is true that in the case of the hemisphere represented in figure 70. I attempt the interpretation of the various conditions exhibited, but I am not at all satisfied that I am even approximately correct. The only furrows which can be recognized beyond doubt are the sulcus fronto-orbitalis, the sulcus præcentralis superior (of which the upper part alone is present), and the two separate parts of the sulcus frontalis superior. I have marked a furrow *f. m.*, thereby indicating the possibility of its being the sulcus frontalis medius, but I fully recognize that there is very nearly as much likelihood of its being a third part of the sulcus frontalis superior.

To judge from the beautiful figures which are given by Waldeyer * † and the two very clear and distinct diagrams of Kohlbrügge‡ there seems to be an absence of the ramus horizontalis of the inferior præcentral sulcus and also of the sulcus frontalis medius in the gibbon. The sulcus frontalis inferior is strongly marked, and stands in connexion with the vertical stem of the inferior præcentral furrow.

* "Sylvische Furche und Reil'sche Insel des Genus Hylobates," Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin, XVII., 1891.

† "Das Gibbon-Hirn," Internationale Beiträge zur Wissenschaftlichen Medicin. Virchow's Festschrift. Band I.

‡ "Versuch einer Anatomie des Genus Hylobates," Zoologische Ergebnisse einer Reise in Niederländisch Ost-Indien herausgegeben von Dr. Max Weber. Band II., p. 189, figs. A. and B. Leiden, 1891.

There is one sulcus in the frontal lobe of the human cerebrum which never occurs in the cerebral hemisphere of the apes. I refer to the sulcus frontalis mesialis, which appears in the first frontal gyrus in the form of two or three separate furrows which occasionally run together. It presents a degree of development comparable with that of the sulcus frontalis superior in the chimpanzee, and I have already alluded to the fact that it is more strongly marked in the European than in the Negro.

XI. **Exposed part of the Insula and the Sulcus Fronto-orbitalis in the Apes.**—The great majority of observers are at one in regarding the inferior frontal convolution in the anthropoid brain to be represented by the small loop of cerebral surface which is bent around the so-called anterior limb of the Sylvian fissure. As early, however, as 1876, Pansch advanced a different view. He says: "What Bischoff, therefore, claims to be the third frontal convolution in the anthropoids is, in my opinion, in its upper part only a small piece of the gyrus frontalis inferior, and in its under part a piece of the uncovered insula."* Kohlbrügge,† in his study of the brain of the gibbon, has arrived at similar conclusions, and I now desire to state that, in this matter, I fully agree with both of these observers.

Pausch is in error, however, in so far that he regards the sulcus fronto-orbitalis as the representative of the anterior limb of the Sylvian fissure. There is no anterior limb of this fissure in the anthropoid brain and there can be no such limb. A Sylvian limb can only be formed by the contact of the opposed margins of two adjoining Sylvian opercula. The posterior limb is formed by the apposition of the fronto-parietal and the temporal opercula. There is no frontal and no orbital operculum in the anthropoid apes, and therefore there can be no anterior

* "Ueber die Furchen und Windungen am Gehirn eines Gorilla," Abhandlungen aus dem Gebiete der Naturwissenschaften herausgegeben vom Naturwissenschaftlichen Verein zu Hamburg-Altona—; Bolau und Pansch, p. 22. Hamburg, 1876.

† "Versuch einer Anatomie des Genus Hylobates," Zoologische Ergebnisse einer Reise in Niederländisch Ost-Indien. Band II., p. 191. Leiden, 1891.

limbs of the Sylvian fissure. The so-called anterior Sylvian limb, is merely the anterior free border of the fronto-parietal operculum.

The fronto-orbital sulcus in the anthropoid brain is the representative of the anterior limiting sulcus of the insula in the human brain. A true anterior limb of the Sylvian fissure could only be formed in the anthropoid cerebrum by the backward growth of the anterior lip of this sulcus in the form of an operculum, and the contact of this with the anterior free border of the fronto-parietal operculum. By such a proceeding the

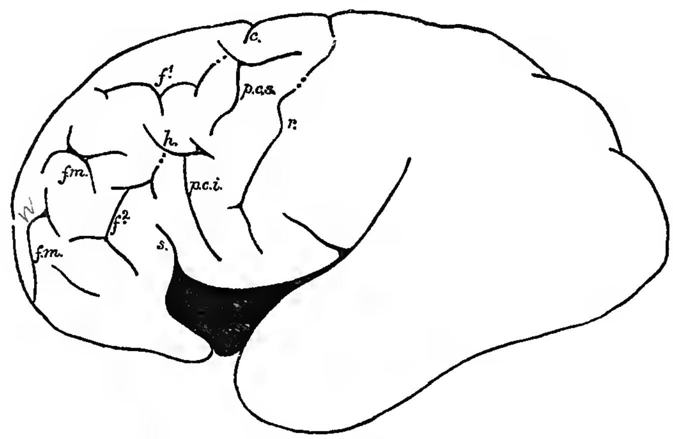


FIG. 71.—Lateral view of the left hemisphere of a female fœtus in the early part of the eighth month of development. Drawn by the American apparatus for tracing orthogonal projections of the skull.

r.	Fissure of Rolando.	*f.*[1]	Sulcus frontalis superior.
p. c. s.	Sulcus præcentralis superior.	*f.*[2]	Sulcus frontalis inferior.
p. c. i.	Sulcus præcentralis inferior.	*f. m.*	Sulcus frontalis medius.
h.	Ramus horizontalis.	*s.*	Single anterior limb of Sylvian fissure.

portion of brain cortex between the anterior free border of the fronto-parietal operculum and the fronto-orbital sulcus, or, in other words, the exposed part of the insula in the anthropoid brain would become submerged as in man.

In our study of this question we should not compare the anthropoid cerebrum with the adult cerebrum of man, but with cerebral hemispheres of fœtuses of the eighth and ninth months of development. At this

stage in the growth of the human cerebrum the insula is still open in front, the frontal and orbital opercula are only partially formed and the resemblance between the anterior limiting sulcus of the insula and the fronto-orbital sulcus of the anthropoid apes is very evident. The similarity is rendered all the more striking in those cases where the frontal operculum in the human fœtal brain fails to appear and the development is therefore tending towards the formation of a single anterior limb of the Sylvian fissure (fig. 71, p. 297).

Figure 1, Plate IV., and figure 33, Plate I., may also be studied from this point of view and compared with figures 9 and 11, Plate IV., which represent the right cerebral hemispheres of a chimpanzee and an orang.

The late appearance of the frontal and orbital opercula in the human fœtal brain and the occasional complete suppression of the former are significant facts in connexion with the total absence of both of these opercula in the anthropoid cerebrum.

In the Gibbon brain Kohlbrügge, in the Memoir already referred to, has made a most important observation which bears directly on this question. He states that in three examples of *Hylobates syndactylus*, as well as in the right hemisphere of a *H. leuciscus* the so-called anterior limb of the Sylvian fissure (*i. e.* the furrow formed by the anterior free margin of the fronto-parietal operculum) joined the sulcus fronto-orbitalis. In these cases therefore the exposed part of the insula was completely cut off from the surrounding surface of the frontal lobe.

But there are other facts which can be brought forward in support of the contention that the portion of cerebral cortex which lies between the anterior free margin of the fronto-parietal operculum of the anthropoid brain and the sulcus fronto-orbitalis is to be regarded as belonging to the insula. We have previously seen (Chapter II.) that the submerged portion of the island of Reil in the chimpanzee and the orang presents very little trace of an anterior boundary, and that it ascends gradually as we trace it forwards along an inclined plane until it finally reaches the free surface of the frontal lobe (fig. 11, Pl. IV.). We have further noted that if the antero-posterior length of the submerged part of the insula in the anthropoid brain be compared with the length of the human insula it is observed to be rela-

tively very much shorter. The length index of the insula in each case is: chimpanzee 18·2; orang 21·5; and man 29·6. If we regard the insula of the anthropoid apes as extending forwards to the sulcus fronto-orbitalis, and measure accordingly, we find that the discrepancy is not nearly so great. In the chimpanzee the length-index of the insula becomes 28; in the orang it becomes 31.

Of course this manner of regarding the homologies of the parts in the lower portion of the frontal lobe is in complete variance with the ideas almost universally held in regard to the inferior frontal convolution in the apes, but it renders the difference between this part of the simian brain and the corresponding part of the human brain still more striking.

If we remove in the adult human brain the opercular part of the inferior frontal convolution we find little, if any, of the gyrus left behind. In other words, the inferior frontal furrow on the surface very nearly corresponds in its position to the deep submerged upper limiting sulcus of the island of Reil. In some cases, however, the inferior frontal furrow lies at a slightly higher level, and in these cases after removal of its opercular part a narrow strip of the inferior frontal gyrus still remains. This non-opercular part of the gyrus corresponds to the greater part of the inferior frontal convolution in the apes. The basal part of the inferior frontal convolution in the anthropoid ape is truly opercular in its nature. It is composed of that part of the fronto-parietal operculum which lies in front of the inferior præcentral sulcus, and corresponds to the similarly situated basal part of the gyrus in the human brain. In short it is the upper part of the gyrus as described by Bischoff, &c., after we abstract from it the lower portion which as we have seen belongs to the insula.

But the non-opercular part of the inferior frontal gyrus in the human brain is much more extensive in the fœtus than in the adult. The inferior frontal sulcus when it is first developed lies considerably above the level of the upper limiting furrow of the island of Reil. In subsequent growth the descent of the opercula appears to be accompanied by a downward movement of the inferior frontal sulcus, so that when the fully-developed condition is reached it is placed in near relation to the upper border of the insula. We have already referred to an apparent downward movement on

the surface of the cerebrum of the early sulcus præcentralis inferior. These growth changes are exceedingly difficult to follow, and they tend to obscure the homologies which exist between the parts in this region of the simian and human brains.

XII. **Topography of the Inferior Præcentral Sulcus.**—The sulcus præcentralis inferior when it is first formed lies relatively further back on the cerebral surface than in the adult. About the seventh month, however, it attains a position which it maintains unaltered in all the subsequent stages of growth. To appreciate these relations it is necessary to construct an index which may be termed the fronto-præcentral index. The cerebrum is measured with the tape from the frontal point to the middle of the vertical limb of the præcentral sulcus, and from this again to the occipital point. The sum of these two measurements is taken as equal to 100, and the index calculated accordingly.

FRONTO-PRÆCENTRAL INDICES IN MAN.

Lateral Length of the Cerebrum = 100.

	Period of Growth.	Number of Hemispheres Examined.	Fronto-præcentral Index.
Intrauterine Life.	Fifth month,	5	39·7
	Sixth month,	5	38·8
	Seventh month,	9	37·7
	Eighth month,	13	37·0
	Full-time fœtuses,	12	
Extrauterine Life.	3 months to 5 years,	10	
	Adults,	46	

There is no sexual distinction to be detected in cor

position of the inferior præcentral sulcus. Twenty-sev

hemispheres yielded an average fronto-præcentral index of 37·9; whilst nineteen female hemispheres afforded an average index of 37·8.

The relative position of the sulcus with reference to the cranial wall is not so fixed. In those instances in which the sulcus appears very early (in the fifth month) it is placed in front of the coronal suture, as we have already mentioned (Pl. II., fig. 9; also Pl. I., fig. 14). In other cases the vertical stem may appear immediately subjacent to the coronal line (Pl. II., fig. 15; Pl. I., fig. 24; and Pl. V., fig. 2), or immediately in front of it (Pl. II., figs. 18 and 20). Between the eighth and ninth months of intrauterine life it is usually found just behind the sutural line or perhaps coinciding with it.

After birth the forward movement of the sutural line becomes more marked as may be seen in the following Table:—

Corono-præcentral Indices.

Lateral Length of the Cerebrum = 100.

Period of Growth.	Number of Hemispheres Examined.	Average Corono-præcentral Indices.
New-born fœtuses, . . .	5	2·0
First year of extrauterine life, .	4	3·7
4 to 5 years, ...	3	4·3
11 to 12½ years, ...	2	4·6
Adult, ...	8	6·4

N.B.—The lateral length of the hemisphere was obtained in this case by one measurement along the lateral surface of the cerebrum from frontal point to occipital point. The corono-præcentral distance was measured from the sutural line to the mid-point of the vertical stem of the fissure.

The steady advance forwards of the suture in relation to the sulcus can be appreciated by an examination of the above indices. It is largely due to the forward growth of the squamous overlapping process of the lower part of the anterior border of the parietal bone (figs. 28 to 31, pp. 119–122).

In the apes, the præcentral sulcus is placed relatively much further forwards on the surface of the cerebrum than in man. The fronto-præcentral indices in several different genera are given in the following Table:—

FRONTO-PRÆCENTRAL INDICES IN THE APES.

Lateral Length of the Hemisphere = 100.

	Number of Hemispheres Examined.	Average fronto-præcentral Index.
Cebus, ...	8	27·4
Baboon, ...	11	28·7
Macaque, ...	6	30·8
Chimpanzee, ...	6	31·6
Orang, ...	2	33·6

The position of the vertical stem of the inferior præcentral sulcus with reference to the coronal suture varies somewhat in different apes. Sometimes it coincides more or less closely with the sutural line. In the various ape-heads figured in Plate VIII. (figs. 18 to 22) it is covered by the coronal bar of bone; in other cases it is placed a short distance in front of the suture (*vide* Plate IV., figs. 8 and 9).

XIII. **Summary.**—1. The sulcus præcentralis inferior in the human brain is composed of a vertical stem and a horizontal limb. The latter is carried forwards into the middle frontal convolution.

2. This furrow is the earliest to appear on the outer surface of the frontal lobe of the fœtal brain. In some cases it is seen in the fifth month cerebrum in the form of a long, deep, vertical sulcus, which subsequently undergoes a retrograde development before its adult condition is reached. In many cases, in its early condition, it presents a form in every respect comparable with that observed in the cerebrum of a low ape (Cebus). Frequently it is developed in several separate pieces.

3. The sulcus præcentralis superior is closely connected with the basal

part of the first frontal furrow. It is usually developed along with it. It consists of two pieces—an upper and a lower—which may be partially or completely separated from each other, as well as from the basal part of the first frontal furrow by an annectant gyrus.

4. Two additional furrows belonging to the præcentral system are occasionally present, viz. the sulcus præcentralis medius and the sulcus præcentralis marginalis.

5. The sulcus præcentralis medius may arise in two different ways: (*a*) it may be formed by the ramus horizontalis of the inferior præcentral sulcus divorced from the vertical stem and assuming a very oblique or an almost vertical direction; (*b*) it may consist of a new element placed between the superior and inferior præcentral furrows, but showing a closer connexion with the former.

6. The sulcus præcentralis marginalis is a small variable furrow which appears on the cerebral surface between the upper end of the sulcus præcentralis superior and the mesial border of the hemisphere.

7. The inferior frontal sulcus may be developed in three portions which afterwards run into each other.

8. Sometimes these parts remain separate; and frequently its mode of development is indicated in the adult brain by the presence of deep annectant gyri.

9. The basal part of the furrow may be developed in direct continuity with the inferior præcentral sulcus; more frequently it is developed independently. In the latter case it often establishes a secondary and partial connexion with the sulcus præcentralis inferior.

10. The sulcus radiatus and the lateral part of the sulcus frontomarginalis of Eberstaller should be regarded as furrows which belong to the inferior frontal system.

11. The sulcus frontalis superior may be composed of three or four elements which may be partially or completely separate from each other.

12. The superior frontal gyrus and the middle frontal gyrus are each partially subdivided into two tiers or subdivisions by furrows which may be respectively termed the sulcus frontalis mesialis and the sulcus frontalis medius.

13. Both of these furrows have secured a firm footing in the human brain, but one only (viz. the sulcus frontalis medius) has established itself upon the brain of the chimpanzee.

14. The sulcus frontalis medius assumes a definite form, and runs in a sagittal direction in the anterior two-thirds of the middle frontal gyrus. In front it is connected with the fronto-marginal sulcus of Wernicke; behind there are usually two transverse furrows, which are sometimes connected not only with the sulcus frontalis medius, but perhaps also with the ramus horizontalis of the inferior præcentral furrow.

15. The sulcus frontalis mesialis consists of several irregular furrows which follow each other in series midway between the sulcus frontalis superior and the mesial border.

16. Sometimes these are joined so as to constitute a continuous furrow which completely divides the superior frontal convolutions into two parts.

17. The sulcus frontalis mesialis is absent or poorly developed in the brain of the negro.

18. When all the frontal sulci are well developed, there are five more or less distinct tiers of sagittal convolutions in the frontal lobe.

19. The frontal furrows may be placed in order, according to their morphological importance, as follows: (*a*) sulcus præcentralis inferior; (*b*) sulcus frontalis inferior; (*c*) sulcus præcentralis superior and basal part of the superior frontal sulcus; (*d*) remaining parts of the superior frontal sulcus; (*e*) sulcus frontalis medius; (*f*) sulcus frontalis mesialis.

20. The sulcus præcentralis inferior and the inferior frontal sulcus are the furrows which are most firmly impressed on the brain of the apes. In Cebus they alone are present; in Callithrix there are also traces of the sulcus præcentralis superior and sulcus fronto-orbitalis; in the baboon there are, in addition, a rudimentary sulcus frontalis superior, and perhaps (?) traces of a sulcus frontalis medius.

21. In the chimpanzee and the gorilla the sulcus frontalis medius is often present in a form precisely similar to that seen in the human brain; in the orang the condition of this sulcus is doubtful; in the gibbon the sulcus frontalis medius is absent.

22. In the chimpanzee, therefore, the same convolution tiers may be

seen as in man with this exception: the superior frontal gyrus is never split into two by a sulcus frontalis mesialis.

23. The inferior frontal convolution of the apes is very different from that in man.

24. The frontal and orbital Sylvian opercula are completely absent in the apes.

25. Consequently, as Pansch and Kolhbrügge have maintained, a portion of the island of Reil is uncovered and exposed on the surface of the cerebrum.

26. The sulcus fronto-orbitalis of the apes corresponds to the anterior limiting sulcus of the island of Reil in man.

27. There are no anterior limbs of the Sylvian fissure in the anthropoid apes. The so-called anterior limb of the Sylvian fissure corresponds to the anterior free border of the fronto-parietal operculum.

28. About the seventh month of fœtal life the inferior præcentral sulcus of the human brain attains a position which it maintains unaltered throughout all the subsequent stages of growth; previous to this it is placed relatively further back on the surface of the hemisphere.

29. At first it is placed in front of the coronal suture. The sutural line, however, moves forward so that the sulcus ultimately comes to lie behind it.

30. In the ape-cerebrum the inferior præcentral sulcus lies relatively much further forwards than in the cerebrum of man. It may be placed either immediately subjacent to, or in front of, the coronal line.

CHAPTER VI.

ON THE TOPOGRAPHICAL RELATIONS OF THE CRANIUM AND SURFACE OF THE CEREBRUM.

BY VICTOR HORSLEY, M.B. LOND., F.R.S.

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Introduction.—The anatomical relationship of the various portions of the encephalon to the enveloping skull, which is commonly spoken of as cranio-cerebral topography, has of recent years been brought to a certain pitch of development in consequence of the important part it plays in the applied sciences of medicine and surgery. It thus happens that in considering the anatomical questions involved, certain regard has to be paid to the localization of functions in the various portions of the hemispheres. The introduction of such matters may seem, in the present case, only necessitated where the value of some subordinate sulcus would not otherwise be apparent, but more recent research strongly tends to show that the structure of the cortex-cerebri is, in so far as it is the basis of differentiated function, divisible into horizontal segments. These considerations make it especially desirable that, at this particular stage of progress, some definite conclusions should be arrived at for the better guidance of future investigation. Since Broca's original essay in 1861, the work already accomplished in the subject has given for so-called practical purposes sufficiently accurate

indications for the localization on the surface of an average head of the chief fissures in the cortex, but what is now required is the topographical determination of the same in the following cases:—

(*a*) Variations due to variation of cephalic index;
(*b*) Variations due to age;
(*c*) Variations due to race;
(*d*) Variations due to sex;
(*e*) Variations due to pressure distortion;*

and it may not be out of place to here allude to the chief points on which further information is most required.

Some anatomists have, it will be seen, already arranged their facts under such a classification as permits of these cardinal divisions being preserved, but unfortunately the methods employed have been so different, and the measurements given so often only absolute and not relative to some general index (*e. g.* the length of the hemisphere, &c.), that comparison of the results obtained by different observers is hardly possible. A very moderate experience of the practical application of topographical procedure shows soon that the systems involving arbitrary lines (especially verticals raised from a base line)† and measurements are apt to mislead, and though giving perfectly true results in some instances, more frequently fail completely with serious consequences. I shall endeavour, therefore, to describe the position of each sulcus and region of the brain with reference to the parts of the skull covering them, and shall supplement the description of each by reference to the arbitrary measurements which have from time to time been recorded; for while disallowing the primary value of such absolute statements, no one is more ready to admit their worth as corroborative adjuncts. It ought to be specially noted that even what should be essential features in such researches are often omitted. Thus it should be

* Not merely has the deformity of the cranium (Broca, Féré, Ecker) to be borne in mind, but the displacement of the sulci and gyri due to increased intra-cranial pressure.

† Merkel has shown, moreover, that in children the base-line, from the external auditory meatus to the inferior margin of the orbit, is untrustworthy.

an invariable rule to take measurements of relative positions of angles only in preparations in which the brain has been hardened *in situ* by suitable injection, and yet in the large majority of cases this simple precaution has not been observed.

Of all the procedures that have been devised, and are enumerated in the Bibliography, none is so accurate as that adopted by Professor Cunningham, namely, hardening the brain *in situ*, removing the bones of the cranium piecemeal, and finally taking an accurate cast of the whole preparation for the better investigation of the topographical details of the specimen. I have twice enjoyed the opportunity of working with such material in his laboratory, and with the aid of his very generous assistance.

Of the remaining methods (*vide* Bibliography), unquestionably those which are designed to express the facts by relative measurement are by far the most valuable, and of them should be selected, as the foremost, the procedure of Müller and the later method of Zernoff (see especially Altoukhoff). Both are capable of very valuable and trustworthy extension.

So far, therefore, these three anatomical methods afford promise of exact results when carried out on the lines above mentioned.

Turning now to the considerations of the localization of function, which in this connexion cannot be disregarded, it is only necessary to draw attention to the fact that the cortex of the excitable region (*i. e.* the central gyri, &c.) must, I believe, be regarded as theoretically divided by lines which are parallel with the margin of the hemisphere, and which, where coincident with the frontal sulci continue the direction of these across the fissure of Rolando into the parietal lobe. Clearly, therefore, it must be the particular object of future research to give reliable data for determining the position of points in lines drawn vertically, or, speaking more correctly, at right angles to the middle line, the longitudinal fissure.

Fortunately the anatomical configuration of the hemisphere and sulci lends itself essentially to the furtherance of this object, and only the accumulation of facts are needed to supply the required information.

In the following summary of the principal facts known on this subject

at the present day, the various divisions and questions are arranged in the order:—

I. Topography of the cerebrum as a whole—its borders.
II. Topography of the cerebrum as a whole—its surfaces.
III. Topography of the fissures separating lobes.
IV. Topography of the furrows subdividing lobes.
V. Topography of the island of Reil.

The conclusions arrived at on these questions by previous observers will be found referred to under each of the above headings.

I. Topography of the Cerebrum viewed as a whole—its Borders.— The margins and surfaces of the cerebral hemisphere are moulded upon the folds of the dura mater and the bony prominences of the interior of the skull. When these are well understood it only remains to point out certain minute details which frequently escape notice. The whole hemisphere, viewed in its uppermost margin and in a sagittal plane, is bordered by nearly a semicircle, the frontal lobes in their lower third alone presenting a flattened surface, the edge of which does not continue the general arc-like curve, but is directed backwards as well as downwards.

On tracing round the lateral margin which separates the lateral from the inferior surfaces, and on starting from the extreme tip (nasion) of the frontal lobe, the margin of the hemisphere rises forthwith as the roof of the orbit slopes upwards as well as outwards, and finally arrives above the outer angle of the orbit which is formed, of course, by the union of the frontal orbital plate with that of the great wing of the sphenoid. As the outline of the hemisphere follows round this outer border of the orbit, it gradually comes to bulge outwards on the alisphenoid just where the ptero-frontal suture commences, *i. e.* at the anterior extremity of the pterion. This bulging edge of the frontal lobe is more marked often in children, and thereby forms a promontory or cape, as Broca called the more posteriorly lying folds of the third frontal gyrus, viz. the pars triangularis. The lateral margin is then lost in the Sylvian fissure, but reappears immediately by crossing it on to the temporal sphenoidal lobe just above the anterior extremity of the parallel sulcus; from

this point it runs forwards at rather less than a right angle to the plane of the orbital roof (*i. e.* in other words, the plane of the inferior surface of the frontal lobe), to form the outer border of the tip of the temporo-sphenoidal lobe where it rests against the posterior portion of the inner surface of the great wing of the sphenoid. The margin of the hemisphere here bends outwards, separating the lateral surface of the temporal lobe from the front aspect of its tip. The line taken by the margin next passes downwards and backwards immediately in front of the course of the middle meningeal artery, and finally runs just outside and above the same where it is entering the skull through the meningeal foramen. From this foramen, which lies at the deepest part of the middle cranial fossa, the line of the margin of the hemisphere ascends over the petrous bone where this latter forms the squamous bone. At the highest level of the petrous bone in this function (*i. e.* the roof of the tympanum), the margin of the hemisphere presents the commencement of the groove which is so obvious on the under surface of the temporo-sphenoidal lobe, and which is simply due to the moulding of the hemisphere over the prominence caused by the long labyrinth. This notch or groove is not noticed in text-books of anatomy, but in consequence of the roof of the tympanum being not infrequently perforated by disease opposite this spot, it assumes a certain importance. I may add, in passing, that it is marked in the new-born infant, the anthropoids, and can be detected in the lower apes, *Macacus rhesus* and *M. sinicus*. The margin of the hemisphere then sinks gently as it passes backwards, and descends to the level of the anterior border of the tentorium; from this spot it shortly rises again, and here the lateral margin is notably indented by a fold of dura mater, raised, apparently, by the temporal veins entering the lateral sinus. This indentation forms a most constant and important notch in the border (and partly the inferior surface) of the temporo-sphenoidal lobe, and, indeed, naturally marks the separation of this lobe from the temporo-sphenoidal. It has received the name of the præ-occipital or Schwalbe's notch, and, besides being produced by the tension (Cunningham) of the veins referred to, is caused, in part, by the growth of the skull at the asterion (which is just a little lower, but in a corresponding line), drawing the dura mater into salient

folds (Cunningham). It may also be easily shown that this region is a distinct acme in the course of the lateral sinus where it arrives about opposite the middle of the cerebellar hemisphere.

From this point the margin of the hemisphere trends downwards over the cerebellar hemisphere, and then curves round upwards to the Torcular Herophili. On the right side where the mesial margin meets the lateral margin just traced, there is a well-marked groove (Bastian), which cuts deeply into the hemisphere, and is produced into the lateral margin a certain distance, being caused by the prominence of the lateral sinus.

To trace, now, the lateral margin of the hemisphere on the exterior of the skull, as we have just followed it on the inner surface, is not so easy. The point of chief difficulty is to determine the lowest point at which the lateral margin crosses the middle fossa. Professor Cunningham has long devoted much attention to this question, and has prepared nineteen preparations from which I have obtained the following facts.

The preparations referred to were made as follows:—After simple removal of the hemispheres the cranial cavity was filled with plaster. Pins were then driven through the skull in the lines of the principal sutures and along the upper margin of the zygoma. On removal of the cast from the interior of the skull the above-mentioned lines were distinctly pricked out upon it. Now, since the point at issue is the amount of the temporal lobe which lies so deeply as to be below the level of the upper border of the zygoma, I made the following observations from the above-mentioned specimens:—

The plane of the under surface of the temporal lobe being easily taken by a plate of glass laid across both lobes, the distance from the ptero-squamal junction to this plane was first measured with compasses, styled Pp., and represented, of course, the vertical depth of the temporal lobe at the commencement of the posterior limb of the Sylvian fissure. From the same sutural point the distance between it and the zygoma (upper border line) was measured and termed Pz. The difference between Pp and Pz gives the total depth (vertical) of the temporal lobe, which is below the *upper border* of the zygomatic arch. The measurements are stated in the accompanying Table.

TABLE SHOWING THE AMOUNT OF THE SURFACE OF THE TEMPORAL LOBE WHICH IS OPPOSITE TO THE ZYGOMA OR BELOW IT.

Number of Specimen.	Sex and Age.	Hemisphere observed.	Pp. mm.	Pg. mm.	Difference.	Index. Pp. = 100.
1.	Female, Adult, . .	Right,	33	28	5	15·1
2.	,, ,, . .	Left,	43	34	9	20·9
3.	Female, 35 years, . .	Left,	37·5	34	3*	8·1
4.	Male, 25 years, . .	Left,	42	35	7	16·6
5.	Male, Adult (No. 4), .	Left,	47	37	10	21·1
6.	Male, Adult, . . .	Right,	40	35	5	12·5
7.	,, ,, . . .	Left,	40	35	5	12·5
8.	Female, 4 years, . .	Left,	34	31·5	3	8·8
9.	Female, 11 years, . .	Left,	32	31	1†	3·1
10.	Female, Adult (No. 4), .	Right,	48	42·5	6	12·5
11.	,, ,, ,, .	Left,	42	35·5	7	16·6
12.	Male, 70 years, . .	Left,	40	32	8	20
13.	Male, 15 years, . .	Left,	40	31	9	22·5
14.	Male, aged (No. 2), . .	Right,	42	35	7	16·6
15.	,, ,, ,, . .	Left,	42	37	5	11·9
16.	Male, aged (No. 5), .	Right,	42·5	31	11	26·1
17.	,, ,, ,, . .	Left,	43·5	33	10	23·2
18.	Female, aged (No. 3), .	Right,	32	22	10	31·2
19.	,, ,, ,, .	Left,	30	21	9	30
			Average Index, . .			17·3

From this Table it follows that if the total vertical depth of the temporal lobe be taken as 100, then, of that amount, 17·3 is situate below the

* Fractions of millimetre disregarded. † Only one pin struck brain.

level of the upper border of the zygoma. It is extraordinary to what a degree this simple projection has been misrepresented by all previous authors. *Vide* the drawings of Turner, Hefftler, Foulhouze, &c.

Finally, from 7 tracings which Professor Cunningham has kindly given me of infants and fœtuses, full term, as follows:—No. 1, new born, ♂; No. 2, new born, ♀; No. 3, three months, ♀; No. 4, six months, ♂; No. 5, seven and a-half months; No. 6, seven and a-half months; No. 7, eight months, ♀—it is evident that in early life the lower border of the temporal lobe either coincides with or only just passes beneath the upper border of the zygoma. Hence the relationship of the two lines as given for children of maturer age and for adults is one of further development.

Viewed sagittally the margin of the hemisphere is readily traced. The line of the edge of the hemisphere runs parallel to the middle line of the skull, *i.e.* the sagittal suture, and distant from it about 5 mm. in the adult, owing to the presence of the longitudinal sinus. As this vessel often lies rather to the right of the middle line, the margin of the left hemisphere commonly approaches the sagittal suture more closely than does the right; but in either case the separation only involves the actual margin, since the sinus is triangular in transverse section, and consequently the mesial surfaces of the hemispheres lie close to the falx cerebri in the middle line, immediately below the depth of the sinus. Similarly the margins of the hemispheres are more separated posteriorly than anteriorly on account of the sinus widening from before backwards. In surgical practice, of course, the localization of the sinus is of far more importance than that of the edge of the hemisphere, but the necessity of defining the margin is obvious when the determination of a lesion therein is required.

In front the margin of the hemisphere descending to the level of the olfactory bulb reaches almost to the nasal suture, connecting the frontal and nasal bones, hence the choice of this point in estimating the length of the hemisphere. From this lowest point a line to indicate the margin may be drawn upwards and outwards over the superciliary ridge (the supra-orbital line) curving round to just below the points uniting the minimal breadth of the frontal bone (Broca), (the end of the supra-orbital diameter of the anthropologists). From this point the marginal line runs backward across the

ptero-frontal suture to reach the posterior point of the pterion, whence it runs downwards or beneath the ptero-temporal suture, but leaving it before reaching the ridge of the pterygoid aspect and surface of the temporal bone to pass backwards to the root of the zygoma, along which it lies at the junction of the process with the skull. Further backwards the line rises gently close above the auditory meatus. Immediately behind the vertical diameter of the meatus the margin of the hemisphere is seen to rise steeply to clear the roof of the tympanum and vestibule as previously described. Having accomplished this the line passes just above, or at the change of the squamous suture into the parieto-mastoid suture. Above this last it runs, rising gently to reach an acme vertically over the asterion, and thus forms the præ-occipital notch. Descending again, it soon crosses the lambdoid suture a short distance above the asterion, and then runs down to almost reach the superior curved line; thence turning up again at an angle of about 30° as far as the middle of the curved line, and following consequently the direction of the latter to reach horizontally the middle line just above the Torcular Herophili, or in other words (*i. e.* externally) the occipital protuberance.

II. **Topography of the Cerebrum viewed as a whole—its Surfaces.**— The customary anatomical description of the surface of the cerebral hemisphere requires a little alteration to adapt it to our present purpose. Topographically speaking the principal points to be studied are:—

1. The inclination and direction of the surfaces.
2. The external position of limiting points, chiefly with reference to the basal aspect.

The *inferior* (*and outer, as it actually is*) *surface* of the frontal lobe rests on the orbital plate of the frontal bone, and adjoining parts of the ethmoid and sphenoid in so far as these enter into the composition of the anterior fossa, the anterior and outer limits having been already described. The posterior margin of the orbital surface is easily defined externally as a line joining the posterior extremities of both portions. This line consequently

also defines the level and locality of the anterior perforated spot, the optic chiasma, and the origin of the middle cerebral artery.

Viewed from the front, the chiasma in the adult extends for about 7 mm. on each side of the middle line, *i.e.* about one-fifth of the breadth of the hemisphere; closely outside it and in front lies the anterior perforated spot, the outer limit of which corresponds with a plane parallel to the mesial plane of the skull, and passing through the middle of the superior orbital margin.

Beyond this plane, and between it and the external or temporal surface of the skull lies the commencement of the Sylvian fossa.

The *anterior surface or aspect* of the temporal lobe includes the small portion lying in front of the lateral border of the hemisphere (*vid. sup.*) and which is made up of the anterior extremities of the superior middle and inferior temporal gyri, and also of the anterior surface of the uncinate gyrus. Each of these components forms about half of the surface in question, but the uncinate portion lies much further back than what is commonly regarded as the tip of the lobe. In fact, whereas the anterior extremity of the tip of the temporal lobe lies in a vertical* plane passing through the junction of the middle and posterior thirds of the (breadth of the) great wing of the sphenoid, *i.e.* projecting under the small wing (according to Féré it reaches 10 to 15 mm.), the plane of the tip of the uncinate gyrus only lies as far forwards as a vertical* plane through the foot of the vertical stem of the præcentral sulcus, or at least the oblique sulcus.

The *lateral surface* of the temporal lobe requires no notice here, as its borders have been described, and the individual gyri and sulci are alluded to further on.

The *inferior surface* of the temporal lobe is limited anteriorly by a line prolonging the lateral margin of the hemisphere to the middle line across the lobe and posteriorly by the parieto-occipital notch. Its middle presents the shallow fossa which is the extension of the notch on the lateral margin, and which coincides with the petrosal elevation. In front of this "petrosal" fossa, the anterior third of the inferior temporal gyrus and a small portion

* *I. e.* at right angles to the middle plane of the head.

of the middle gyrus rest on the floor of the middle fossa, *i.e.* on the anterior portion of the petrous bone, the inferior portion of the squamous, and the posterior margin of the great wing of the sphenoid.

The inner and posterior limiting border of the inferior surface of the temporal lobe is coincident with the margin and attachment of the tentorium, against the anterior extremity of which the uncus lies.

The aspect of the inferior surface of the temporal lobe is directed downwards and backwards.

The *inferior surface* of the occipital lobe is continuous with that just described, but rests wholly on the tentorium. Owing to the very marked median elevation of the vermiform process of the cerebellum, the line which marks the separation of the median aspect of the lobe from the inferior, rises from the tip of the occipital lobe to the splenium of the corpus callosum, thus taking a line which is almost at right angles to the parieto-occipital fissure. The result of this is, that although the calcarine fissure is situated on the mesial aspect of the lobe, it lies close to the margin of the inferior surface. The inner half of the inferior surface of the occipital lobe is occupied by the lingual lobe, the remainder by the adjoining occipito-temporal gyri.

In consequence of the outward slope of the tentorium, the general aspect of the inferior surface is directed downwards, forwards, and inwards, the reverse of that of the temporal lobe; the region where these opposed planes meet is above the "vertical" plane of the pulvinar, *i.e.* just below the splenium of the corpus callosum.

The remaining surfaces need no special description beyond the details furnished later respecting the topography of their individual parts.

III. Topography of Fissures.—Class I. Those separating Lobes :—

(*A*) Sylvius.
(*B*) Rolando.
(*C*) External Parieto-Occipital.

(*A*) Fissure of Sylvius.—In the adult, the commencement of the fissure of Sylvius at the anterior extremity of the Sylvian fossa is, by

almost every author, localized on the external surface of the skull, beneath the pterion. Now, as is well known, the form of the pterion varies according to the relative share taken in its formation by the component bones, but for the European races it may be assumed to be always in the shape of an H. Under these circumstances it becomes a matter of much importance whether the posterior end or the centre or the anterior end of the parieto-sphenoidal suture, represented by the horizontal bar of the H, is to be taken as the pterion. Whether, in short, the ptero-temporal or the ptero-frontal junction indicates the origin of the fissure of Sylvius. Accepting the account given in Chap. II. of the configuration of the fossa, the origin of the posterior limit of the fissure will far more often be found in the adult beneath the ptero-temporal extremity of the ptero-parietal suture, and this point should therefore, for the purpose of localizing the commencement of the fissure of Sylvius, be regarded as the pterion *par excellence*. The trunk portion of the fissure, running, as it does, just along and posterior to the edge of the lesser wing of the sphenoid, where that divides the anterior and middle fossæ of the base of the skull, is situated in a line drawn about transversely, *i. e.* at right angles to the plane in which the pterion lies. It reaches, of course, to the anterior perforated spot, and which lies just external to the anterior clinoid process. The general direction and relations of the branches of the fissure are as follows:—

The anterior limbs run forwards beneath the line of the pterion to just beyond the coronal suture. The posterior branch or limb, in the adult, courses backwards along the squamous suture, leaving it just beyond the highest point of that line, and running towards the lambda.

The topography of these component parts of the fissure will now be separately considered.

The Topography of the Anterior Limbs.—In localizing on the external surface of the head the position of the anterior limbs of the fissure of Sylvius, we are unfortunately met with the difficulty that the anterior limbs are not constant in form. The commonest and, since Broca's time, most received view is that there is in the adult an *ascending* limb, rising from the seat of origin of the posterior limb, cutting the frontal operculum

in front of the lower end of the sulcus præcentralis inferior, and that there is a *horizontal* limb running straight forward from the same seat of origin, cutting the fronto-orbital operculum. These two anterior limbs enclose the promontory (*i. e.* "Cap" [cape] of Broca).

Where these two anterior limbs are present their topographical relation to the exterior appears to be, in the adult, as follows:—

The *ascending* anterior limb starts from the angle of the ptero-squamous junction, *i. e.* the posterior extremity of the horizontal portion of the pterion, and from thence runs upwards under or just in front of the coronal suture, crossing that line a short distance above the pterion. Sometimes, when the præcentral sulcus is further back than usual, the anterior ascending limb has been seen to run upwards just behind the coronal suture.

The *horizontal* anterior limb extends along the horizontal part of the pterion; in other words, along the upper border of the great wing of the sphenoid.

These relations of the anterior limbs are notably altered in their vertical level by age. Thus before the fifth year, when the squamous borders of the basal cranial bones are not yet fully developed, the whole of the Sylvian fissure is nearer the temporal ridges than the sphenoid and squamous sutures; and further, owing to the late development and growth of this region—when the line of the coronal suture moves forward (see Cunningham, p. 156)—it overtakes the ascending limb of the fissure, which in the full-term fœtus lies in front of the suture.

In the infant and young child, as just stated, the position of the anterior limb is further forwards and higher up when projected on the cranial vault. This has to be noted in connexion with the commencement of the posterior limb of the fissure.

The point at which separation of the limbs occurs is, owing to the non-descent of the upper opercula, far above the pterion, and may be considered to descend close in front of the coronal suture. At birth it is just above the anterior extremity of the pterion line, *i.e.* at the ptero-frontal junction. From this point it very slowly recedes posteriorly along the pterion line, till the common adult position is arrived at. In a noteworthy proportion of cases the point lies, however, not at the ptero-temporal

junction, but, as it were, arrested and opposite the middle of the pterion line, *i.e.* the upper border of the great wing of the sphenoid.

The Topography of the Posterior Limb.—The first point to be determined in the topography of the posterior limb is the all-important relationship which the body of this deep fissure bears to the squamo-parietal suture. Since, as is well known, this relationship varies greatly with the age of the individual, it is necessary, in determining topographically the situation of the posterior limb of the Sylvian fissure, to first discuss the conditions that prevail in the child, and later the relations of the fissure in the adult. Fortunately this has been exhaustively treated by Prof. Cunningham (see page 140 of this Memoir). On page 142 Prof. Cunningham sums up his conclusions, viz. that at the time of meeting of the opercular lips, *i.e.* shortly after birth, the fissure and suture are furthest apart, that up to the fifth year they approach each other rapidly, that after the fifth year this occurs more slowly, and that it is not until the ninth year that the adult relationship of the two structures is attained.

In the Child.—Under these circumstances the accurate position of the posterior limb of the Sylvian fissure in the infant and young child can only be arrived at in the following manner:—The origin of the limb being already determined (*vid. sup.*), and the highest point in the squamo-parietal suture noted, a "vertical" is drawn through this at right angles to the mesial plane, and carried down to below the zygoma. The next step is to determine the whole temporo-parietal depth of the surface of the hemisphere. This is unfortunately not easy. The upper limit of the hemisphere is readily marked, of course, but the lower border can only be roughly estimated, according to the data given on p. 141, to lie just below the level of the lower border of the zygoma. The temporo-parietal length obtained in this manner is obviously open to the damaging criticism that it is estimated by tape measurement over the soft parts and zygomatic arch, which carry the line so far outwards as to cause error by lengthening it. As a matter of fact the error produced is balanced by the fact that any lengthening of the more or less vertical outer line is only equal to the marked curve of the surface of the hemisphere itself; and we have only to regard the thickness of the enveloping cranium and scalp at the upper

point. This we may take (Parchappe, Broca, Welcker, Merkel, and others) to vary between 5 and 1 cm., and considering that the measurements are made with pressure the lower limit may be taken as the working amount to deduct.

I have found by trial on the cadaver that this mode of application of the indices is sufficiently accurate to be a reliable guide. Having obtained the temporo-parietal depth, it only remains to measure off the parietal depths as given by Prof. Cunningham, and which for convenience are reproduced here.

Temporo-Parietal Depth = 100.

Period of Growth.	Parietal Depth.	
	Right.	Left.
7½ to 8½ months fœtuses,	60·6	61·4
Full-grown fœtuses,	61·0	62·4
First year of life,	64·6	62·5
4 to 5 years,	65·9	65·4
11 to 15 years,	69·7	68·8
Adults,	69·7	68·5

(The figures given for the adult will serve to check off the localization of the posterior limb of the fissure, as given on p. 144.)

Until we are in possession of a large series of facts, determined by Professor Cunningham's mode of preparation, and by relative measurements, the above-described method of ascertaining the position of the central portion of the posterior limb of the fissure of Sylvius can only be regarded as of approximate value. The same point can also be obtained, after the situation of the squamous suture is noted, by means of the Sylvio-squamous Index given in tabular arrangement on page 141; but in this case the same source of error prevails, viz. the temporo-parietal depth.

In the adult.—In the adult, on the contrary, it is usually conceded by most observers that the posterior limb of the Sylvian fissure coincides with the highest point of the squamo-parietal suture. While this is sufficiently generally true, it is to be noted that the correspondence may be incomplete, and the fissure consequently above or below the suture. This is possibly to be chiefly ascribed to defect of the growth, which, as Professor Cunningham has sufficiently shown, occurs in the squamous part of the temporal bone, causing the latter to push upwards and overlap the corresponding portion of the parietal bone. In any case, however, the possible error of localization ought* not in absolute measurement amount to more than five millimetres, except in very rare cases, indeed; therefore, for "practical" purposes (which usually means the employment of a fairly large opening), the removal of even a centimetre disc would expose the fissure with almost absolute certainty.

The determination of the topography of the hinder extremity of the posterior limb is, however, not so simple.

The posterior limb of the Sylvian fissure customarily terminates in one of two ways—(*a*) it suddenly turns upwards at an angle (about 100°), often bifurcating and ending close to the parietal eminence; (*b*) it continues in the line of the limb and terminates below the parietal eminence, but little further back than the vertical plane of the termination in (*a*).

The possibility of correctly estimating the situation of the end of this limb is not rendered easy by these variations. Further, the absolute necessity of dealing only with brains hardened *in situ* limits greatly the material on which to found an answer to the problem. From an examination of fifteen heads, of all ages, prepared by Professor Cunningham, the termination was in ten cases as in (*a*); and in the remainder, *i.e.* 33 per cent., as in (*b*), but with tendency towards (*a*) in two cases.

The impossibility of determining which form of termination exists in

* This is not an inappropriate place to point out the very serious and dangerous defects (especially on the point here described) of the large folio plates recently constructed by Adamkiewicz: Wien. 1892. These plates, which purport to be a guide to the surgeon, will, if relied upon, be a fertile source of disaster rather than success, and, as such, should, in the interests of humanity, be withdrawn from publication.

any given case makes it absolutely necessary to study the relation of both to some known point. That usually chosen is the parietal eminence. The centre of this can readily enough be ascertained as the extremity of a line joining the maximal transverse diameter through the eminences of each side. Under these circumstances it is found that the ending termed (*a*) lies just in front of the centre of the parietal eminence, whereas the ending termed (*b*) lies in a line drawn at right angles to the mid-line through the parietal eminence, and at a variable distance below the latter, often in merely the line of direction of the posterior limb.

For the present nothing more definite can be stated of the topographical localization of the termination of the limb.

(*B*) Fissure of Rolando.—Of all the fissures most attention in topography has been paid to that of Rolando. In accordance with what has been stated in the introductory section of this chapter it is obvious why this should have been the case. Before directly examining the facts of anatomical and topographical relationship of the fissure to surrounding structures it is essential to dwell for a moment on certain features already partly described by Prof. Cunningham. Of these the first are the characteristics of the course taken by the fissure.

The *upper end* of the fissure cuts the mesial margin of the hemisphere, and turns backwards and downwards, in part forming the upper limit of, in part subdividing, the paracentral lobule. For topographical purposes the point at which the fissure cuts the margin of the hemisphere is taken to be the "*upper end*" of the fissure, and is the very important point on which so many measurements have been taken.

The *course* of the fissure, namely, its sinuous line of direction is according to most observers, marked by two bends, spoken of respectively as the superior and inferior genu. Of these the latter should be topographically regarded as of immense importance. This is dwelt upon in the introductory remarks (also on p. 334), and need not be repeated; but in special confirmation of what is therein stated are the observations of Prof. Cunningham and of Eberstaller, given on pages 173–4, respecting its developmental history. It will therefore be specially necessary to consider, later on, the topographical relations of the inferior genu.

The *general direction* of the fissure has hitherto always been taken as a straight line connecting the upper and lower ends of the fissure, and this will be employed in the present pages; but for accurate delineation of the fissure on the exterior of the skull, it is very important to notice that the actual line taken by the fissure is an oblique one downwards and forwards in the upper third of its course, *i. e.* to beyond the superior genu; then chiefly forwards and also somewhat downwards to the inferior genu, and from thence almost straight* downwards (including forwards) to its termination in the lower end. From this it follows that whereas the upper part of the fissure fairly coincides with the *line of general direction*, the noteworthy region of the inferior genu is considerably above and in advance of this latter.

The *lower end* of the fissure may terminate as usual (Hefftler and all observers) a few millimetres above the Sylvian fissure, or it may cut† the operculum, and enter the last-named fissure. For present purposes the latter variety, which occurs relatively rarely (19 per cent., Cunningham), will be ignored, and the fissure regarded as being separated from the fissure of Sylvius by a narrow annectant gyrus. Reference to the point now omitted will be made in describing the topographical value of the subordinate sulci.

In proceeding to discuss the means of topographically determining on the exterior, with accuracy, the position of the fissure and of its component parts, especially the inferior genu, the factors of age and sex are naturally of much importance, although of not such influence as in the case of the fissure of Sylvius. The changes they produce will be touched upon under each point. The facts may here be arranged according to the principal features of the fissure, and to which allusion has just been made.

The Upper End.—The determination of the position of the upper end of the fissure of Rolando has been accomplished in various ways, which may be grouped thus—

(*a*) *Relative Measurements.*
(*b*) *Absolute Measurements.*

* Almost perfectly straight in the orang.

† Not completely as in the sense understood by Giacomini and the majority of anatomists.

(*a*) *Relative Measurements.*—The far higher value of relative measurements is sufficient reason for not dealing with the question of the topography of the ends of the fissure chronologically.

Thane stated that if the total distance from the fronto-nasal suture, *i. e.* the nasion to the inion or occipital protuberance, were taken and divided equally in two, that a spot ½ inch behind the halfway point in the nasio-inial line would mark the upper end of the fissure.

Hare, by examining a series of 10 heads with the cerebrum *in situ*, came to the conclusion that in front of the upper end of the fissure we should find ·55 of the total length from the glabella to the inion.

Prof. Cunningham has shown that the position of the upper end of the fissure of Rolando is very constant in relation to the rest of the hemisphere. Further, that in comparing the position of the upper end to the bregmatic portion of the coronal suture the distance lengthens during the passage from the sixth month of intra-uterine life to the adult state two-fold. This difference* of 2 to 1 is, however, lost to a large extent by birth, and the difference then is as 18 to 16, the length of the hemisphere being 100. In employing these facts for localization it would be necessary to allow for the thickness of the skull and coverings in taking the length of the hemisphere which is to form the basis of the calculation; but whatever mode of finding the upper end of the fissure be employed, these indices will sufficiently correct the position according as that is altered by age. Another important practical point discovered by Prof. Cunningham is that there is a sexual difference in this question, the average corono-Rolandic indices upper and lower, and in the male and female, respectively, being 16 and 12·1 for the former, and 17·5 and 13·9 for the latter.

The same fact is also shown to be true by Altoukhoff.

Muller by an ingenious and original method determined the position of the chief sulci as follows:—Measuring from the glabella to the inion he took a mesial arc, *i.e.* the usual antero-posterior distance, and in addition a horizontal arc between the same points. By then simply dividing these two arcs into one hundred equal parts, and joining them at intervals of

* In confirmation, consult the evidence obtained from the lower apes.

ten units, he obtained lines which divided the head into proportionate amounts of a perfectly relative kind. His results in consequence are particularly valuable.

He found that in the mesial plane the upper end of the fissure of Rolando was situated as follows:—

In skulls of 18 cm. and more in mesial length, the upper end of the Rolandic fissure was at a point of 56·5 per cent. of the mesial arc measuring from the glabella; while for skulls below 18 cm. it is less, namely, 55 per cent. of the same arc. As a general average Müller finally obtained 55 per cent. as the most accurate result. Reid's method of erecting a perpendicular on a basal-orbital inial line, at a point which he names "the posterior border of the mastoid process," is often quoted as a relative measurement, but it has no claim to be considered as an accurate guide, since the posterior border of the mastoid process has an *antero-posterior* extent of some 2 cm., and consequently is by no means a definite point. Moreover, the whole procedure of erecting verticals on base lines to localize what lies at the vertex is so obviously open to such gross error that this and similar methods ought to be discarded entirely.

Le Fort states that, contrary to Hare and the majority of English and American observers, he has not found the upper end of the Rolandic fissure at approximately ·557 of the sagittal arc length, but at a mean distance of ·532. Curiously, in contrast to what he states earlier in his work, he goes on to say that the distance is even less in dolichocephalic heads, *e.g.* ·520, and more in brachycephalic, viz. ·545.

Debierre found, as all preceding him, that the upper end of the fissure is measured from the front 55 per cent. of the glabella-inion arc.

Giacomini employs a special method. He first takes the maximal transverse diameter of the cranium; then having drawn the usual sagittal line, he connects the two extremities of the transverse diameter by a line drawn at right angles to the mesial plane. The line connecting the two extremities of the maximal diameter must, of course, cut the fissure of Rolando at a certain point and at a certain angle. Where the Rolandic line cuts the transverse diameter line, and makes an angle with the latter, he finds by measurement that on the average that angle varies from 30 to

35 degrees. It is clear that a variable point in this method is the termination of the greatest transverse diameter; and Giacomini himself admits that out of twenty-eight hemispheres, it fell twelve times in the superior temporal fissure, *i.e.* in the parallel sulcus, nine times in the third temporal convolution, and seven times in the middle temporal convolution. The point at which he estimates this transverse diameter of the plane cuts the fissure of Rolando in a majority of cases is half way between the sagittal suture and the end of the greatest transverse diameter. This point, he says, out of the twenty-eight cases, fell fourteen times exactly in the fissure of Rolando, six times behind it, and eight times in front of it. When the line of the fissure of Rolando fell, as it did in one exceptional case, posteriorly to the estimated position, he found it was due to a remarkable degree of brachycephaly, the index being 94·3. In examination of these latter measurements considered with the question of the proportional shape of the head, he came to the conclusion that the distance of the upper end of the fissure of Rolando from the coronal suture averaged 55 mm. in the dolichocephalic head, and 54·4 in the brachycephalic, and that of the lower end from the coronal suture was in the former case, 26·5 mm., but in the brachycephalic only 20·08.

(*b*) *Absolute measurements.*—The confirmation of the foregoing conclusions may be made by employing the data obtained from absolute measurements of the distance of the "upper end" of the fissure of Rolando from the highest point of the coronal suture. Such data are as follows:—

Observer.	No. of Cases Examined.	Distance of Rolando (upper end) from Coronal Suture.
Broca,	—	4·7 cm. (In 1861, of 11 males, 4–6·3 cm.)
Hefftler,	20	4·8 cm. (mean).
Turner,	—	4·4 (mean).
Foulhouze,	9	5·0 (mean).
Championnière,	—	5·5 cm.
Féré,	—	4·7 to 4·8.
Hare,	—	4·76.

Observer.	No. of Cases Examined.	Distance of Rolando (upper end) from Coronal Suture.
Giacomini,	—	4·7 (mean); min. 4; max. 5·4.
		Brachyceph., 54·4. } Rel.
		Dolichoceph., 55·0. } Rel.
Poirier,	'large number.'	4·8 cm.
Passet,	—	5·16 (mean).
		Males, Brachyceph., 5·66.
		Males, Dolichoceph., 4·83.
		Females, Brachyceph., 5·08.
		Females, Dolichoceph., 5·13.
Chiarugi,	12	5·28 mean.
		Brachyceph., 5·35.
		Dolichoceph., 5·22.
Le Fort,	—	4·955.
		Brachyceph., 4·8.
		Dolichoceph., 5·1.
Dana,	Children.	Either ·55 of total length, or as follows:—
		In one case 3 cm. behind bregma.
		" " 3·8 " "
		" " 4·0 " "

Regarding the variations produced by external deformity of the cranium, Broca found in the flat head of Toulouse that the upper end of the fissure was carried backwards, being 5·7 cm. from the coronal suture, whereas the *maximal* normal previously observed by him had been 5·6 cm., and the average 4·7.

Ecker was not able to exactly determine this difference in the Vancouver flat head, owing to failure of material.

Féré states that in plagiocephaly the upper end of Rolando moves forwards on the side on which the parietal boss is most prominent. This, of course, is in harmony with the fact that that is the brachycephalic side. The difference on the two sides amounted to about 0·4–0·5 cm.

The general direction and the topography of the lower end of the Fissure.—It will be advisable to deal with the above-named points before commencing to discuss the more important, but more difficult, special localization of the points in the course of the fissure, notably the inferior genu.

It will, of course, be obvious that whereas the upper end of the fissure may be reasonably easily fixed, it is quite otherwise with the lower end. To gain the topography of this point is a *sine qua non.* It can be accomplished with accuracy in one of three ways—either (1) the angle which the fissure of Rolando makes with the middle plane of the body having been measured, and the site of the upper end known, the true general direction of the fissure is found, and having been drawn on the surface of the head, and having been terminated just above (2–5 mm.) the fissure of Sylvius, the terminal point thus obtained is the position of the lower end; (2) the lower end of the fissure can be estimated by determination of the relative indices which express the distances between it and the neighbouring sutures; these calculations are then confirmed by making absolute measurement of the distances in question; (3) by Zernoff's *encephalometer.*

(1) *The determination of the lower end of the fissure of Rolando by finding the general direction of the fissure.*—Hare, having previously shown that the average angle made by the fissure of Rolando with the middle line was 67°, it occurred to me that a plan based on this fact would secure the localization of the lower ends of the fissure, that of the fissure of Sylvius being well known. For this purpose I had constructed a simple brass instrument, consisting of two narrow strips of metal fixed at an angle of 67°, and marked in inches. It was then easy, by placing this on the head with the juncture of the parts corresponding to the previously determined locality of the upper end of the fissure, to draw the line of the fissure with considerable accuracy, and so denote the lower end. Wilson, at the instigation of Chiene, improved very greatly the form of my instrument, but substituted for the exact measurement of the distances required in the mesial plane, Hare's proportional scale, the graduation of which was indicated, not by figures, but by letters, of such character that if the position of the inion corresponded to a capital letter, the upper end of the Rolando was opposite to a small letter of the same name. This plan, although

ingenious and simple, nevertheless did not provide for sufficient accuracy. In endeavouring to consider how an improvement might be effected, it appeared clear that the solution lay in a true calculation of the angle which the fissure makes anteriorly with the middle line. The researches of Meyer had shown the effect of arrest of the cranial growth in determining a greater or less degree of transversality in the direction of the cerebral fissures. It was probable, therefore, that if the cephalic index were properly determined, a distinct relationship would be shown to exist between it and the Rolandic angle. For this purpose I made a number of measurements, under the kind guidance and correction of Professor Cunningham, of the invaluable material—viz. brains hardened *in situ*—in his laboratory, since this question can at present alone be answered upon a basis of such preparations.

In studying the literature of cerebral topography I was interested in finding that the probable truth of this idea had been foreseen by the prescience of Broca, as Foulhouze records that in a conversation with him he had suggested that some sort of relationship of this kind would possibly be found to exist. Moreover, that Rüdinger had stated that the difference in proportionate lengths of dolicho- and brachy-cephalic heads was particularly due to growth of the mesial border of the parietal bone, so that the ascending gyri in brachycephaly had a more transverse direction, and the opposite in dolichocephaly; and that further, the upper end of the fissure of Rolando was situated a greater distance behind the bregma in dolichocephaly than in brachycephaly. This last point all observers' measurements quite confirm, except Le Fort. Further, that in the female the direction of the parietal sulci made a smaller angle with the middle line than in the male. Passet, working under Rüdinger's direction, found, in brains previously injected and measured *in situ*, that the average angle in males was 60·9°, in females 64·2°. On the other hand, Professor Cunningham has taken up the point, and, as may be seen on pp. 186 *et seq.*, has come to the opinion that there is no sexual difference in the angle of different individuals, that the average adult angle is 71·7°, and that its degree rises and falls with the respective variations of the cephalic index.

On estimating the possible error in the localization of the lower end of the fissure if the angle were not properly determined,* I found it amounted to about 2 mm. for each degree; consequently, it is possible, in using a cyrtometer without the correction about to be proposed, to fall into an error of 2 cm., or more than the breadth of an ascending gyrus, a very serious mischance. To remedy this I further improved, in 1890, on Wilson's modification of my instrument, by first fixing a button on the end of the mesial band, so that the commencement of the longitudinal graduation should commence exactly at the nasal suture or nasion, and not at the glabella. It is unfortunate that by agreement of anthropologists the glabella was fixed upon as the point limiting anteriorly the cranium in maximal length, since its position is not definite on the mesial plane. Zernoff, who discards, for this reason, the glabella as a fixed point, states that he takes "the frontal point of Broca." It is difficult to know what he means by this statement, as Broca never speaks of a frontal point. It is clearly not the ophryon. There remains, therefore, only the nasion, and the instruction for employing his encephalometer bears this out. I have followed Thane in measuring the mesial length from the naso-frontal suture (nasion) as giving the final *cranial* limit, and cannot regard the employment of the glabella as a satisfactory starting-point. The mesial band can be easily steadied and fixed in position by employing the brow-band, as introduced by Wilson. The total distance between the nasion and the inion having been accurately read off in centimetres and millimetres, it is divided in half, and *one centimetre* (Thane's point modified) added to the result. An arc, with an adjustable (Rolandic) arm fixed by a screw, is now slid on to the mesial band, an index being fixed above the arc, and distant 6 cm. from the axis about which the Rolandic arm turns, marking finally the spot at which the upper end of the fissure lies. The point of the index (put for clearness

* Poirier, after measuring the angle in fifty hemispheres, has found (1891) the angle varied within limits of considerable extent.

† Debierre has recently constructed a goniometer for the same purpose, and states that, from certain measurements, he finds the average Rolandic angle to be 65°. Mine is made by Mr. Hawkesley, 357, Oxford-street, London.

behind the arc) is consequently opposite a number equal to $\frac{1}{2}$ total distance + 1 cm. + 6 cm.

The Rolandic arm of the instrument is now turned until its arrow-pointed end is exactly opposite the degree which the fissure may be supposed to make according to the cephalic index previously ascertained. It is then secured firmly with a turn of the screw. The Rolandic arm has a long slot in its centre, so that all that is now required is to draw a brush carrying some aniline dye down the slot almost as far (2–5 mm. Hefftler) as the line marking the fissure of Sylvius.

It only remains to state to what use this instrument may be put in cases of different cephalic index.

Theoretically what was sought for as an ideal was a sliding scale of parallel columns, the one giving the units of the cephalic indices, and the other giving the corresponding variations in the angle. Unfortunately, the material at my disposal was too small, and at present I believe we are not justified in making more than the following rough rule:—

Accepting 69° as the average* angle which the fissure makes with the middle line in the adult British head, then the angle may be expected to increase or diminish by one degree for a corresponding increase or diminution of two units in the cephalic index. In the absence of exact facts such a conclusion, of course, does not pretend to be more than an estimate, but as such I have found it to be practically useful.

A further assistance in this matter is derived from a knowledge of the length of the fissure. The correct degree to which the line in this method should be drawn has just been given, viz. as far as within a few millimetres of the line which denotes the posterior limb of the fissure of Sylvius; but an extra aid to control of the estimate is the average relative length of the fissure. As Cunningham truly says (p. 190), the absolute length is of no value in determining this point. Measuring the whole sinuous line of the fissure, and, in addition, the length of the hemisphere, Cunningham's figures afford the only evidence on this point. To avail ourselves of the indices he has thus found, the procedure must be as follows:—Having found

* The mean between Hare's 67° and Cunningham's 71°.

the "total length of the hemisphere measured by the tape along its superior border," * and regarding that as 100, then the relative—*i. e.* percentage length of the fissure—according to him, is as follows for the different ages:—

Full-term fœtus,	32·8
First year,	35·8
4 to 5 years,	33·9
11 to 15 years,	36·1
Adult,	39·3

Hence, for any given age, the length of the fissure can be fairly accurately estimated, and employed to control the preceding plan.

Kohler recognized that the most important extremity of the fissure of Rolando is the lower one. He employed for the determination of this an instrument constructed as follows:—A sagittal iron band is laid over the medium plane of the head, and so fixed that it lies over the root of the nose in front and the occipital protuberance behind; two rods which are to mark the vertical lines suggested by Reid are fixed into small collars which slide in a slot in the central band. A rod which is to mark the situation of the fissure of Rolando is hinged at its upper end to the sagittal band, and it slides in a spring slot on the anterior vertical rod, so that it can take any position and direction. In applying this instrument the central band is first laid on the head in the usual way, and then the anterior vertical rod is pushed backwards until its lower end lies in the præauricular fossa. The second vertical is similarly pushed backwards parallel with the first until it strikes the posterior border of the mastoid process, if the upper end of the rod is placed at a point which is 55·5 per cent. of the total length of the naso-occipital distance.

In this way Kohler, while apparently modifying Reid's method, really employs a procedure very similar to that described on page 324. He, of course by relying on the mesial plane as a starting basis, secures sufficient

* The obvious error will be due to the measurement of the hemisphere being too large unless the thickness of the scalp and skull is eliminated.

accuracy for guiding the vertical lines; but the plan cannot be accepted as an absolutely reliable indication of the lower end of the Rolandic fissure.

(2) *The determination of the lower end of the fissure of Rolando by measurement of the distances between it and the surrounding sutures.*

(*a*) *Relative Measurements.—Müller* (*vid.* p. 324) found that, by his important method of vertical and horizontal arcs, he could localize the lower end of Rolando as follows:—

In skulls of a sagittal length of 18 cm. and over, the lower end of the Rolandic fissure = 45·5 to 45 per cent. of the horizontal arc measured from the glabella.

In skulls of a sagittal length of less than 18 cm. the percentage was greater—viz. 46 per cent. of the arc. The general average finally obtained by Müller was 42 to 43 per cent.

Reid's method involves the following procedures:—

(1) Drawing a base line from the inferior border of the orbit to the centre of the external auditory meatus.

(2) Erection of a vertical line on (1), starting from the præ-auricular depression, and continued up to the line marking the posterior limb of the fissure of Sylvius. Where these two latter intersect is the position of the lower end of the fissure.

Apart from the fact that the Rolandic fissure terminates in the large majority of cases (see p. 163) above the Sylvian fissure, this method is disadvantageous, from the fact that it depends on a base line which is always fallacious, and the anterior end of which is not in relation with the cranium, but with the facial bones (see also p. 307.)

Makins and Anderson employ a combination of relative and absolute measurement, and conclude that the lower end of the Rolandic Fissure lies between the intersection of a line joining the mid-sagittal point* and præ-auricular fossa, with one ("squamosal") joining the external angular process of the frontal bone and the junction of the middle and lower thirds of the former line ("frontal"), and a point three-eighths of an inch in front of such intersection. It is clear that this rather more arbitrary method shares many of the errors involved in Reid's plan.

* Found by halving the distance between the glabella and inion.

Poirier, after determining in the adult, by absolute measurement, the usual position of the lower end of the fissure, states that a relative method of value is the following:—After having measured the distance from the præ-auricular fossa to the sagittal line, the relative distance of the lower end of the Rolandic fissure from the auditory canal is to the total auriculo-sagittal length as 7 to 17. He came to this conclusion after having examined, in various ways, no less than 94 heads.

Féré, taking the length of the hemisphere *with callipers*, states that the distance from the frontal pole to the lower end of the fissure of Rolando, is 44 per cent. of the whole length.

(*b*) *Absolute Measurements.*—Employing, as in the case of the upper end of the fissure, absolute measurements to confirm the conclusions arrived at respecting the lower end, I find that the following such data have been recorded:—

Observer.	No. of Cases Examined.	Distance of Rolando, lower end, from Coronal Suture.
Broca, ...	11 (males).	2–3 cm.
Hefftler, . . .	20	2·8 cm.
Giacomini, . . .	—	2·8.*
	—	Brachyceph. case, 2·008. Dolichoceph. case, 2·65.
Lucas Championnière, .	—	A horizontal line is drawn from the external angular process of the frontal for 7 cm. From the posterior extremity of this line a vertical is raised 3 cm. high. The upper end of this should correspond with the lower end of the fissure of Rolando.
Poirier, . . .	large number.	2·8 cm.

The Topography of the Sinuosities of the Rolandic Fissure.—Of the sinuosities that have been described to occur in the fissure of Rolando, and said by Passet to be more marked in the male than female, two alone

* From the context it does not appear whether Giacomini, in making this statement, is quoting from his own observations or from Hefftler's.

may be at present regarded as relatively constant or of morphological significance and functional importance. These are the superior and inferior genu respectively. In the human brain these are almost invariably marked, and possess, as far as my observations go, a constant relation to the neighbouring sulci, of the following general character:—

The inferior genu.—The more important inferior genu lies midway between the horizontal level of the superior (or first) frontal sulcus and the upper end of the præcentral sulcus, while it is exactly opposite, *i.e.* on the same level as the centre of the sulcus præcentralis medius when that is present, free or joined, as most commonly it is, to the posterior or superior branch of the inferior præcentral sulcus.

Under these circumstances, and having regard to the position of the sulcus præcentralis superior and its direction, it is obvious that the lower extremity of this sulcus bears an important relation to the genu, and assists in defining its position on the exterior of the head. On page 300 are given the indices whereby this point is fixed. Between it and the fissure of Rolando lies the principal area of representation of the upper limb.

Messrs. Anderson and Makins have stated that, on obtaining tracings of the whole length of the fissure of Rolando, comparison of the drawings failed to show a constancy in the sinuosities, and that from the curvatures of the fissure alone it was not possible to fix the position of the genu. Exception ought to be taken to the methods employed, inasmuch as the brains from which the tracings were made were not previously hardened; but there is no doubt that, in certain exceptional cases (probably brachycephalic) in which from the shallowness of the sinuosities and the want of antero-posterior direction, it is difficult to fix the position of the genu from only the aspect of the fissure. Under these circumstances additional assistance may be obtained by determining first the lower end of the superior præcentral sulcus and the position of the middle præcentral sulcus.

Finally, as regards the grouping of points of localization of function about the inferior genu and which render close attention to it necessary, reference may be made to Papers by Dr. Beevor and myself in the Philosophical Transactions since 1887.

The *superior genu* lies near the separation of the respective limb areas,

but usually below this level, and consequently has not much value from this point of view. Further it is a curve of much larger radius than the inferior genu, and for this reason is less easy of determination. In general, it is just below the level of the main axis of the superior frontal sulcus, the denotation of which affords sufficient guidance to it.

(*C*) External Parieto-Occipital Fissure. — The external parieto-occipital fissure is generally taken (Broca,* Bischoff, Hamy, Hefftler, Seeligmuller), as coinciding at its upper extremity with the apex—*i e.* the highest and most anterior point of the lambdoid suture, or as it is termed by anatomists the lambda.

But it is abundantly clear from the observation of the position of the fissure in the lower apes, as well as the study of its relative position during development, that the upper end of the fissure is well in front of the lambda in earlier stages, and that it is only in adult man, and to a less degree the adult anthropoid that it approaches, becomes coincident with, or even in rare cases lies a little behind the lambda.

For present purposes it would therefore be advisable if possible to arrange the facts according to a sliding scale of age, as well as to take the average position in the adult.

Unfortunately the only evidence on the first point is founded on comparatively few observations which bear a relative value to the growth of the skull, viz. those made by Cunningham. (See Chap. I., pp. 62 *et seq.*, of this Memoir). His observations, however, are not only perfectly definite on the main issue, but are abundantly confirmed by the less valuable (because not relative to the growth of the skull) facts collected by Féré, Foulhouze,† Hamy, Symington. The summary of the evidence adduced by these observers, collated with Cunningham's, permits of the following conclusions:

1. From fœtal life to the fifth year the index of the relative distance of the external parieto-occipital fissure *in front* of the lambda is 4 to 4·9.

* In his first Paper describing his employment of the peg method, Broca states (1861) that in 11 males the parieto-occipital fissure coincided with the lambda, and was rarely in front of it.

† Having had the opportunity of examining and measuring the specimens deposited in the Musée Broca, it is gratifying to bear witness to the accuracy with which the measurements of Dr. Foulhouze were made.

2. From the fifth year to adolescence the distance between the fissure and the lambda is notably reduced.

3. In adult life the fissure lies in the large majority of cases just in front of the lambda. (Relative position 2·9 ; mesial length of hemisphere = 100 ; absolute measurements averaging about 5 mm.)

4. In adult life the fissure not infrequently coincides with the lambda, and very rarely lies behind it. According to Passet the fissure in the male is usually further forward than in the female. (*Cf.* Altoukhoff.)

IV. Topography of Furrows.—Class II. Those subdividing Lobes:—

(*A*) FRONTAL LOBE.
(*B*) PARIETAL LOBE.
(*C*) OCCIPITAL LOBE.
(*D*) TEMPORAL LOBE.

(*A*) FRONTAL LOBE—*The Topography of the Subordinate Sulci.*—The numerous sulci on the frontal lobe will now be dealt with under the names adopted by Professor Cunningham in Chapter V., page 244.

Sulcus Præcentralis Inferior.—Of these the most important is the sulcus præcentralis inferior, or, as it is more usually termed, the præcentral sulcus simply. Around the various portions of this sulcus are grouped most important foci of representation of various regions of the body.

For the present purpose we have to consider—

(*a*) The vertical stem.
(*b*) The focus of branching.

(*a*) The vertical stem lies, in the large majority of cases, behind the coronal suture in its lower half. In a small number of cases it coincides with the suture, but in most instances is set some millimetres posteriorly to the bony line in question.

Professor Cunningham has shown that the inferior præcentral sulcus, like the Rolandic fissure, is remarkably constant in its relative position to the rest of the hemisphere, the index being 37·8 when the maximal length

of the hemisphere is taken from the frontal to the occipital poles, this regarded as 100, and then the index calculated from the front.

In this and the next index the *surface* of the hemisphere was measured; hence in the entire head the index would practically still apply, since the errors due to variations in the thickness of the skull and scalp would not be appreciably different in the observations.

Whereas the coincidence of the sulcus and suture is commoner at birth, the advance forwards of the sutural line in subsequent years carries back the position of the sulcus relative to the exterior.

By the employment of the indices given by Professor Cunningham on p. 300 in the manner just indicated, the vertical stem of the sulcus may be fixed with fair approach to accuracy. I have tested this on the cadaver.

(*b*) The focus of branching of the sulcus is a point of exceeding importance from the fact that it, in both the lower and higher apes, marks the separation of the representation of the conjugate deviation of the eyes from the facial movements. To determine the position of this point which marks a horizontal level, it was necessary to have a relative measurement made on preparations of unquestionable exactitude. To obtain this I took as a basis line easily capable of external measurement the distance from the bregma to the centre of the external auditory meatus, and determined the index for the distance on this line of the bregma from the bifurcation focus of the præcentral sulcus (inferior). The measurements gave the following indices:—

Age.	Sex.	Heads Measured.	Bregma-Præcentral Index.
Children up to 11 years, .	Males, . .	4	40
	Females, . .	3	40·6
Adult, ...	Males, . .	5	38·2
	Females, . .	3	42·7

Although the number of heads available is relatively few, still the facts obtained are so definite as to make it clear that the indices afford a good

guide to the localization of the upper limit of the fissure (*i. e.* its vertical stem). On this point it should be mentioned that where the rare case of no definite focus of subdivision exists, the point taken lies in the bregmatico-auricular line.

In order to obtain a further assistance, I examined in the adult the relation of the stephanion to the præcentral sulcus. In the exceptional instances in which the sulcus coincided with the coronal suture the stephanion lay nearly over the bifurcation point of the sulcus, and further, that where the sulcus lay behind the coronal suture, the temporal ridge, traced backwards beyond the stephanion, would, in most cases, be found to pass over the particular point. As a confirmatory guide this line is consequently useful. (See Plate VII.) Of course this only applies to the head after puberty.

Sulcus Præcentralis Superior.—This sulcus, which, until the writings of Jensen, was regarded as simply the hinder end of the superior frontal sulcus, occupies an extremely constant position. It presents practically the shape of a T lying horizontally, the cross arms being at right angles to the margin of the hemisphere.

The horizontal part or stem of the T joins with the superior frontal sulcus, and will be considered directly.

The present point to decide is the position and extent of the superior præcentral sulcus. Its antero-posterior position on the outer surface is easily found. If a line be drawn upward in the direction of the sulcus præcentralis inferior to the sagittal suture, then the sulcus præcentralis superior will be found to lie midway between this line and the fissure of Rolando. It thus lies, as it were, in the ascending frontal gyrus, notably diminishing the breadth of this convolution in its upper part. The next fact relating to its topography is the determination of its greatest extension downwards. This is a significant matter, inasmuch as the lower end of this sulcus comes into close relationship with the inferior genu of the fissure of Rolando, and consequently it approaches the delimitation level of the respective representations of the upper limb and face.

To obtain an accurate index of the mean position of the lower end of this sulcus I have taken as a basis line the distance from the sagittal suture

to the squamous suture, both of which can easily be felt in the entire head (*vide* Introduction). The indices obtained were as follows:—

Age.	Sagittal Præcentral Index.	—
1–7 years, ...	44	Sagittal squamosal length = 100.
7–16 years, ...	48	
16–106 years, . . .	54	

There is no reason to suppose that the superior præcentral sulcus has aught but a constant relation to the rest of the hemisphere, and the above-stated results are doubtless chiefly due to the well-known upward growth of the squamous suture line (*vide* p. 143).

The position of the sulcus, so far as its relations to the fissure of Rolando and the coronal suture are concerned, will be given under the sulcus frontalis superior.

Sulcus Frontalis Medius.—This small and very subordinate sulcus, which is often present as a mere branch of the inferior præcentral, is nevertheless in an important situation, topographically speaking, since it tends to limit anteriorly the representation of the upper limb, and since it borders the area which, on certain data (these, however, being clinical, are very imperfect), is credited with being the so-called graphic centre (*i. e.* for writing). As a matter of fact, excitation experiments in the lower apes show distinctly that this is the area for extension of the wrist, and other movements essential to the function of writing.

Topographically, this small sulcus is also important as lying in the same level as the inferior genu of the fissure of Rolando.

Projected on the exterior of the skull, this sulcus lies midway between the points the topography of which has just been described, viz. the upper end of the vertical stem of the inferior præcentral and the lower end of the superior præcentral.

No difficulty, therefore, attends its determination, and when fixed it will assist in localizing the region of the inferior genu.

Sulcus Frontalis Superior vel Primus.—This, the superior frontal sulcus of most authors, possesses a very important topographical significance, because the level it forms (see Introduction), if continued backwards, is a very valuable dividing line morphologically, since it separates the representation of the respective limbs. Its line is nearly parallel to the contour of the hemisphere, trending inwards anteriorly, and terminates posteriorly in the centre of the sulcus postcentralis superior. The projection of this sulcus is easy so far as its vertical depth is concerned, since it lies intermediately between the margin of the hemisphere and the inferior genu of the fissure of Rolando. Antero-posteriorly, it becomes very important to determine the point of junction of the superior frontal with the superior præcentral sulcus. From examination of the series of casts in the Broca Museum I found that in 18 the position of this point was as follows :—In 10, it was midway between the coronal suture and the fissure of Rolando; in 3, at the junction of the anterior two-thirds and posterior third of the interval; in 3, at the junction of the anterior three-fifths and posterior two-fifths; and in 2, just posterior to the centre of the interval in question.

From these observations it is clear that the point is a constant one, and varies between midway and the junction of the two hinder thirds, *i. e.* within limits of about 1 cm. of absolute length. Examination of Professor Cunningham's preparations shows the same relations to exist.

Age does not seem to play a noteworthy influence in this measurement, the ages of the above varying from one month to 71 years, without concomitant and regular variation of the proportional distance. However, it is to be noted that in measuring the interval in an infant the bregmatic extremity of the coronal suture must be taken, by continuing the direction of the bony union ; otherwise, if the edge of the bone bounding the lozenge-shaped space be taken as the starting-point, the distance obtained will be curtailed anteriorly.

The topography of the anterior three-fourths of the superior frontal sulcus has at the present time no particular import; we may therefore pass on to the next sulcus.

Sulcus Frontalis Inferior vel Secundus.—By reason of this sulcus bordering the upper limit of the classical third frontal gyrus it has acquired

noteworthy value. However, it is doubtful, whether, as a "level," it separates two very different forms of representation from each other. It is certain that in the anthropoid as in the lower apes there lies immediately around its hinder end the most important cortical area in which the movement of the conjugate deviation of the eyes is represented, but that this is limited to about the posterior third of the sulcus. With this hinder part, therefore, of the furrow, we are chiefly concerned in projecting the sulcus on the exterior of the skull.

Age plays a very influential part in determining such projection. In early life, while the Sylvian fissure is still high above the squamo-parietal suture, this sulcus, which is so truly parallel to the Sylvian fissure, is correspondingly high above the superior temporal ridge and stephanion; but as development proceeds, this, the inferior frontal sulcus, descends, until in the large majority of adults it corresponds, with relatively slight deviations, to the temporal ridge. The posterior end of the sulcus, which is so important, terminates in the lower apes just below the horizontal limb of the inferior præcentral sulcus, but pointing in direction at the præcentral angle, *i. e.* the angle which the ramus horizontalis makes with the vertical stem. The important conclusions to which observation of this fact has led Prof. Cunningham, and the modes of conjunction of the sulci, he has stated on page 287. From an examination of 63 hemispheres to determine not only the exact point of conjunction, but also the direction of the furrow, I found that the relation of this hinder end of the inferior frontal sulcus to the inferior præcentral sulcus was as follows*:—

It joined the anterior branch of the ramus horizontalis	in 38	per cent.
,, pointed at ,, ,, ,,	,, 25	,,
,, ,, the upper end of the vertical stem (*i. e.* the locus of bifurcation),	,, 19	,,
,, joined ,, ,, ,,	,, 11	,,
,, ,, the vertical stem	,, 3	,,
,, pointed at ,,	,, 3	,,

From this it follows that it can be topographically determined within fairly close limits by the means employed for localizing the upper end of

* These observations completely confirm the view taken by Professor Cunningham, that in Macacus the so-called sulcus rectus (*w* of Beevor and myself) is the inferior frontal sulcus of man.

the vertical limb of the latter furrow. As moreover the representation of motor function is more closely connected with the præcentral sulcus itself, the projection of the inferior frontal furrow is readily made with sufficient accuracy.

Sulcus Frontalis Medius.—This sulcus which lies intermediately parallel to the two chief frontal furrows just described, divides longitudinally, when present, the middle frontal gyrus. As such it comes frequently into relation with the frontal eminence.

Sulcus Frontalis Mesialis.—The secondary and very subordinate furrows which subdivide the superior gyrus are so close to the border of the hemisphere as to practically coincide with it. Moreover, they are not known to have any topographical significance.

Sulcus Frontalis Diagonalis of Eberstaller.—This value of this small furrow as a landmark, which has only quite recently received attention from anatomists, is in the Macacque (*Macacus sinicus*) a sulcus of remarkable constancy, and an index of limitation of representation.

In 1887 it was so described by Beevor and myself, we provisionally regarding it then as being from its position possibly homologous with the anterior ascending limb of the fissure of Sylvius. But from an examination of 63 human hemispheres (of which 15 were of children below 15 years, the rest adults), I am convinced that this sulcus is homologous with the sulcus diagonalis of Eberstaller, and this latter therefore, is worthy of some detailed attention. Prof. Cunningham, however, thinks that the small sulcus in the lower apes is the homologue of the sulcus termed fronto-orbitalis in the anthropoid, and this he identifies with the anterior limiting furrow of the island of Reil in man. In the same way he regards the anterior limb of the fissure of Sylvius in the anthropoid to be only the termination of the fronto-parietal operculum.* In the anthropoid the results of excitation by Beevor and myself would seem to suggest that this view of the homologies of these sulci will have to be tested by further research. In the meantime it is sufficient for our present purpose to note that the sulcus diagonalis is necessarily dependent for its topographical position upon the

* It must be observed that this would not dispose of the idea, that at least the upper border of this sulcus is truly homologous with the upper border of the human anterior Sylvian limb.

anterior vertical limb of the fissure of Sylvius, inasmuch as it lies between the latter and the inferior præcentral furrow. The anterior vertical limb we have seen before to be comparatively inconstant in its relation to the cranial vault, but on the whole to frequently arise behind the coronal suture, and to pass upwards and forwards, soon cutting the former line, and coinciding with it or passing in front of it. The sulcus diagonalis extends between the angle formed by the union or proximity of the inferior præcentral and inferior frontal sulci, and the line of the anterior ascending limit of the fissure of Sylvius; for this reason it most frequently lies just behind the coronal suture.

Sulcus Fronto-Marginalis.—This furrow, of some import morphologically, is nevertheless at present without much interest, inasmuch as the function of the region of cortex it divides is as yet unascertained. First observed by Wernicke, this sulcus is now well recognized as the termination of the sulcus frontalis medius. It is transverse in direction, and lies immediately above the orbital margin of the frontal lobe, running inwards and outwards. On the inner side it reaches nearly to the margin of the longitudinal fissure, but on the outer side it either stops short or its place is taken by a subordinate sulcus or sulci. This sulcus subdivides the anterior extremity of the middle frontal gyrus and the outer and angular border of the convex surface of the frontal lobe, and consequently lies close beneath the supra-orbital line of Broca, which gives the minimal frontal diameter, and, as he stated, marks the place of separation of the cranium and face.

Sulcus Transversus Inferior.—Eberstaller has so termed a small subordinate sulcus, which, in 1887, Semon and myself noted to be a very important landmark of representation of function * in the brain of the lower apes (*Macacus sinicus* and *M. rhesus*). It sub-divides vertically the foot of the ascending frontal gyrus.

During an examination of probably more than 300 hemispheres of Macacus, I have never seen it absent. While, however, of this evidently high phylogenetic importance, its relations to the gyrus alter in

* It separates the chief representation of adduction of the vocal cords from the representation of the higher and outer facial movements, and further (Beevor and myself) the separation of the pharyngeal movements from those of the jaw.

constancy in the anthropoid and man. Prof. Cunningham has accounted for the cases of its apparent absence by following Eberstaller in believing that the fissure of Rolando in such cases opens into the fissure of Sylvius, more or less completely, by joining with the sulcus in question. This condition, however, does not always prevail; and I have seen absence of the sulcus transversus and termination of the fissure of Rolando in the usual position in the orang.

On account of its functional importance in the apes I made special observation of its occurrence in man. Of the sixty-three hemispheres before mentioned it was present in 48, *i.e.* 76 per cent. of the cases examined. Of 37 hemispheres in which the variations of the furrow were drawn, the sulcus in two cases was double, *i.e.* in addition to the customary notch proceeding from the Sylvian fissure (for the development of the sulcus, see Prof. Cunningham's statements, p. 173), the condition invariably seen in the Macacque was coexistent; in six other cases the latter alone was present. The remainder, the large majority, opened more or less deeply into the fissure of Sylvius.

It is difficult, in the absence of exact knowledge of the differentiation of the facial region of the human cortex, to appreciate at its proper value this subordinate sulcus, but as the Macacque monkey's brain has proved such a trustworthy guide before, it will be well now to remark upon the topography of this apparently insignificant furrow. Lying as it does, subdividing the foot of the ascending frontal gyrus, its topographical (frontal lobe) projection demands only the ascertaining (according to description already given) of the posterior limb of the fissure of Sylvius, the lower end of the fissure of Rolando, and inferior præcentral sulcus respectively. Midway between the two latter is the position of the sulcus transversus inferior.

Sulcus Orbitalis.—The differentiation of the orbital sulci with the exception of the spinal fissure, is as yet not of known functional importance. The orbital sulcus has therefore been considered under the heading of the *orbital surface* of the hemisphere.

(*B*) PARIETAL LOBE.—The topography of the parietal lobe at the present time leaves a great deal to be desired. In fact the differentiation of the

chief fissure sub-dividing it is only brought towards completion by the present work of Professor Cunningham. Under these circumstances no indices of real value being forthcoming, only the following generalizations are possible.

The boundary fissures—*i.e.* Rolando, parieto-occipital, and Sylvius—having been determined and plotted out on the surface by the methods already described, the further sub-division may be proceeded with.

Sulcus Postcentralis Superior.—This sulcus, which may properly (Cunningham) be looked upon as a separate item from the rest of the intraparietal furrow, is relatively easy to fix topographically, since it runs remarkably parallel with the upper half of the fissure of Rolando. The chief point, therefore, to be determined is its upper extremity. This is to be localized by its distance from the bregmatic point in the coronal suture. The upper end of the fissure of Rolando, having been determined beforehand, and the mesial plane position of the superior præcentral sulcus, the distance between these is on the average almost equal (rather greater) to the distance between the Rolandic fissure and the superior postcentral sulcus. As the postcentral sulcus is certainly a posterior limit of representation in the Macacque, and apparently so also in the anthropoid (Beevor and myself), the fixation of the above point is of value.

From its upper end the direction of the sulcus will be accurately marked by drawing a line parallel to the fissure of Rolando for the upper half of the latter furrow.

Sulcus Intraparietalis—(*a*) *Ramus Postcentralis Inferior.*—As a matter of accuracy the lower and anterior part of the intraparietal sulcus, constituted as it is usually understood to be, is better spoken of as the ramus postcentralis inferior. Under these circumstances it becomes essential for topography to determine what part corresponds to the ends of the intraparietal sulcus in the lower apes, as that has been shown (Ferrier, Schäfer and myself, Beevor and myself) to be a very definite limit of representation. For information on this point we must naturally depend upon Professor Cunningham's observations in Chapter IV. Taking the lower end first, consideration of the facts shows that the inferior postcentral sulcus, as such, does not exist in the Macacque monkey, unless the view of some anatomists is

acceded to, viz. that the subordinate sulcus which divides the foot of the ascending parietal gyrus is the precursor of the sulcus postcentralis inferior in man.

The Sulcus retrocentralis transversus of the Macacque is, I believe, the human sulcus retrocentralis transversus of Eberstaller. It is present in the anthropoids; and when in man the inferior postcentral sulcus terminates in the fissure of Sylvius, it is, as Professor Cunningham points out, by fusion with the post- (or retro-) central sulcus.

The transverse retrocentral sulcus lies in advance of the line of the inferior postcentral sulcus, and practically bisects the lower end of the ascending parietal gyrus. In the Macacque it never cuts the margin of the Sylvian fissure, but in man it does so in the very large majority of cases. The topographical position of this sulcus is intermediate between the line of the postcentral sulci and the fissure of Rolando, the fissure of Sylvius having been previously determined.

To return to the inferior postcentral sulcus, it follows from what has been said that the lower end of this furrow in man is not determinable with certainty. The upper end, which coincides with the anterior extremity of the sagittal portion is, however, the more important, and its topography may now be considered. The reasons of its influence (from the functional point of view) is that in the Macacque monkey and in the orang this point lies behind and below the inferior genu of the fissure of Rolando, and divides (in the ascending parietal gyrus) the representation of the upper limb from that of the face.

If in man the inferior postcentral sulcus is a separated element, it will then be found that the sagittal intraparietal sulcus terminates as in the apes, and consequently its topographical position coincides (posteriorly to the breadth of the ascending parietal gyrus) almost with the level of the genu in question. As a matter of fact, it will be below (as well as behind) the genu, in proportion as the latter is well marked, *i.e.* approaches a right angle. Allowance must therefore be made for this.

(*b*) *Ramus Sagittalis.*—The localization of this, the main part of the intraparietal sulcus, depends on the proportionate development of the superior and inferior parietal lobules. Unfortunately a decision on this subject is

uncertain. (See Rüdinger, and cf. Professor Cunningham's remarks, p. 236.) It may be said that at the commencement of its course it lies midway between the longitudinal and Sylvian fissures respectively; but it runs upwards and inwards so as to pass at a near distance the outer end of the external parieto-occipital fissure.

For the length of this latter we have no reliable data, and therefore must assume it arbitrarily to vary in man from 1 to 2 cm. in length. Although such absolute figures are almost useless, they are in this particular the only facts before us.

Thus the supramarginal gyrus underlies almost exactly the centre of the parietal eminence. The special observations of Féré in this particular are confirmed in general by all who have explored this region. The same topographical localization naturally gives the posterior extremity of the superior temporal gyrus (*q. v.*).

The topography of the inferior parietal lobule is so far easy that it simply consists of the supramarginal gyrus with the sub-divisions of the same, such as are produced by the branches of the sagittal portion of the intraparietal sulcus. The lower margin is, of course, fixed by the determination of the site of the posterior limb of the fissure of Sylvius. It is, however, very difficult in the absence of minuter investigation than at present exists to express the situation of the angular gyrus with real accuracy.

The Calloso-marginal Sulcus.—The localization of the situation of the calloso-marginal sulcus in the entire head is simplified in so far as that it lies close to the middle line. Anteriorly its limit bisects the distance between the frontal pole of the hemisphere and the rostrum of the corpus callosum. This latter point has been observed by Altoukhoff alone.

Posteriorly the calloso-marginal sulcus rises when opposite the level of the point where the fissure of Rolando cuts the margin of the hemisphere and joins the same edge midway between the fissure of Rolando and the parieto-occipital fissure. It thus limits postero-inferiorly the representation of the lower limb on the inner surface of the hemisphere.

Corresponding with its extremities is naturally the extent of the major

part of the gyrus fornicatus vel calloso-marginalis, constituting the anterior two-thirds of the limbic lobe.

Similarly it will be remembered that the determination of the posterior extremity of the calloso-marginal sulcus gives the anterior limit of the quadrate lobule, the posterior border of which is found by fixing the parieto-occipital fissure.

(*C*) OCCIPITAL LOBE.—The gyri of the occipital lobe are all contained within such a limited area, viz. little more than the area of the superior occipital fossæ, as to make their topographical exposure a matter of no difficulty. Moreover, at the present moment the arrangement and homologies of so many of the sulci are still questions *sub judice* that no stress can profitably be laid upon the situation of such furrows as are commonly described, except the most evident.

Sulcus Transversus Occipitalis.—Of these the first is termed the sulcus transversus occipitalis, and by some the sulcus occipitalis superior. This I think Prof. Cunningham has certainly shown to be simply the bifurcated extremity of the intraparietal sulcus (ramus sagittalis). It corresponds commonly with the junction of the superior and middle third of the distance between the lambdoid suture and the superior curved line, the highest point of which marks the lower margin of the occipital lobe. The furrow which is frequently termed the *inferior sulcus* divides horizontally the remnant of the outer surface of the lobe, and bears the same relation to the border of the hemisphere as the middle temporal sulcus does further forwards.

Fissura Calcarina.—The great importance of the calcarine fissure in relation to the representation of central vision is obvious from so many considerations as to make the exact determination of the fissure very necessary. The fissure terminates posteriorly by a bifurcation which, according to Professor Cunningham, is more correctly the middle portion of a "posterior calcarine sulcus." This bifurcation has a vertical direction, and lies usually upon, sometimes, just inside the margin of the hemisphere. The point to be fixed is the junction between it and the horizontal portion of the rest of the fissure. In the first place this point is always well above and in front of the occipital pole. At present it is only possible to estimate

roughly its situation between the latter-named point and the parieto-occipital fissure. If this distance be taken as 100, then the distance from the parieto-occipital fissure to the marginal level of the calcarine, and from thence to the occipital pole, is about as 75 to 25.

Since the evidence from experimental and clinical research coincides with Professor Cunningham's morphological conclusions that it is the apex of the cuneus lobule, or, in other words, the anterior portion ("stem," see p. 42) of the calcarine fissure, it is important to note the depth of this from the surface. This is easily ascertained, since a vertical line dropped through the site of the parieto-occipital fissure passes also through the apex of the cuneus. Almost the whole, therefore, of the mesial surface of the occipital lobe above the level of the torcular Herophili consists of the cuneus. The lingual lobule, lying as it does between the calcarine fissure and the collateral sulcus, lies partly against the falx cerebri, *e. g.* immediately below the calcarine fissure, but for the most part it is in contact with the tentorium (*vid.* inferior surface of lobes).

The groove formed in the right hemisphere by the pressure of the lateral sinus deviates the margin of the hemisphere to the right.

(*D*) Temporal Lobe.—The exposure of the temporal lobe correctly being a matter of much practical value, it is necessary first to mark the situation of the fissure of Sylvius. The next point is the determination of the lower limit of the surface of the lobe, which is just beneath the outer part of the cranium. We have already seen that the margin of the hemisphere corresponds with, in the majority of cases, the centre of the zygomatic arch, or at least its upper border. It now remains to determine what part of the hemisphere composes this, the lower border of the "free" part of the temporal lobe. In every case it is the third temporal gyrus, and it is the centre of the gyrus. Thus, there is for present consideration on the outer surface of the lobe the following parts:—the *superior temporal sulcus*, or parallel sulcus, the *middle temporal sulcus*, the *superior*, *middle*, and *upper half* of the *inferior temporal gyri*, respectively.

(*a*) *Sulcus Temporalis Superior vel Parallelis.*—This sulcus commences anteriorly usually exactly at the squamo-sphenoidal (pteral) suture; it then runs backwards very parallel to the fissure of Sylvius, crossing, like the

latter furrow, the squamo-parietal suture, and then coursing upwards and backwards under the parietal bone. The line it takes from the suture divides very nearly the lower border of the parietal bone at the junction of the middle and posterior thirds, and this may be at present taken as sufficiently exact in the absence of more accurate details.

From this point it courses upwards towards the lambda, so as to cut off a surface of cortex corresponding to a triangular piece of the parietal bone, including the postero-inferior angle of the same. This statement applies only in the case of adults. In the child the posterior third of the parietal bone more correctly corresponds with the portion of the occipito-temporal region below the parallel sulcus.

In considering the topography of the posterior end of this very important sulcus, the first feature is its relation to the parieto-occipital fissure. The two extremities of these furrows tend to approach one another. That of the parallel is right in advance of the parieto-occipital, which is lying at or more often just in front of the lambda. Consequently if they near each other, it is by the parieto-occipital coursing outwards parallel to the lambdoid suture, and separating this line from the hinder end of the parallel sulcus.

The next feature to be described is very vaguely obtained, viz. the second part of the so-called "pli courbe." The first part is known as the supra-marginal gyrus, the topography of which has already been mentioned, and the second the angular gyrus.

The angular gyrus, which is so marked a feature in the lower apes as a simple gyrus of angular outline, is much sub-divided in man. Its commencement, commonly spoken of as the anterior limb, corresponds in site with the posterior portion of the supra-marginal gyrus, *i.e.* just behind the centre of the parietal eminence. Since the parallel sulcus almost invariably runs towards the margin of the hemisphere, and either directly or by the introduction of a subordinate sulcus, delimits externally the second annectant gyrus, the "anterior limb" of the angular gyrus in man may be said to commence above and just behind the centre of the parietal eminence. It now remains to determine the point round which the gyrus changes direction and forms the posterior limb. This point the upper and posterior

end of the parallel sulcus is, as just stated, not readily determinable, inasmuch as the sulcus is not always continuous, but may be interrupted, either by bifurcating, or by the appearance at greater or lesser depth of bridging gyri.

If it bifurcate, the anterior of the two branches turns upwards and forwards to run at right angles, or even less, to the middle line. In any case, it invariably lies behind the centre of the parietal eminence.

Inferiorly the posterior limb of the angular gyrus runs downwards parallel to the lambdoid sutures, and practically midway between the latter and the central point of the parietal eminence, until crossing beneath the squamo-parietal suture, it appears beneath the centre of the squamous bone, and forms the second and broadest gyrus of the temporal region. The degree to which it occupies the surface of the lobe varies with the development of the superior temporal gyrus. As already stated, this proportion usually amounts to the breadth of the second gyrus, being equal to the combined breadths of the superior gyrus and the upper half of the third, as exposed on the outer surface of the lobe above the lower margin of the hemisphere. Therefore, in the adult, the temporal portion of the superior temporal sulcus lies approximately opposite the junction of the upper and middle thirds of the squamous bone.

In the child, up to seven years, owing of course to the relation of the squamous suture to the hemisphere, the highest point of the suture, at first opposite the centre of the broad middle temporal gyrus, gradually comes to coincide with the superior temporal sulcus. The hinder part of the sulcus maintains, however, at all ages, the direction and course described above in relation to the lambdoid suture and parietal eminence respectively.

The Middle Temporal Sulcus.—The anterior two-thirds of this sulcus are readily fixed topographically, namely, as running parallel to the inferior border of the hemisphere, and distant from it one-fourth of the breadth of the temporal lobe. Posteriorly the sulcus courses under the squamous suture, and most frequently terminates just above the asterion, *i.e.* at or in front of the lambdoid suture. So often is this sulcus divided into three portions, an anterior, middle, and posterior, each roughly corresponding to thirds of its length, that the asterial portion may appear as a

separate subordinate sulcus crossing the lower and posterior angle of the parietal bone (in the adult).

V. **Topography of the Island of Reil.**—The topography of the island of Reil is necessarily easy to fix roughly, after that the position of the Sylvian fissure is determined as stated on page 317. The exact position, however, of the sulcus circularis Reillii varies with the development of the vallecula. To project the limiting outline of the insula on the exterior of the cranium, therefore, it is necessary to define the average covering of the vallecula space by the various opercula, and this is best studied by transverse sections. The temporal operculum has such a broad basis in the temporal lobe as to make the level of the temporal limiting sulcus difficult of accurate determination. In the vertical plane through the lower end of the fissure of Rolando, it corresponds externally with the level of the parallel sulcus and upper border of the middle temporal gyrus. Since from this point anteriorly the line of limitation trends downwards, it gradually crosses posteriorly the superior temporal gyrus to reach the fissure of Sylvius at the point indicated by the Table of Indices elaborated by Professor Cunningham (see page 107), and that in the adult corresponds in the antero-posterior direction with the anterior extremity of the ramus sagittalis sulci intraparietalis. This, it will be seen, is just in front of the vertical plane of the posterior surface of the pulvinar.

The upper limit of the fronto-parietal opercular depth is similarly found to lie in the vertical plane through the lower end of Rolando, short of the upper ends of the transverse sulci (Eberstaller). Certain it is that this upper portion is notably narrower than the lower, and that the parietal operculum is relatively shallow. Anteriorly the frontal operculum is similarly shallow—in fact more so than the parietal, and *à fortiori* than the temporal operculum. The covering gyrus is the lowermost portion of the promontory of the third frontal gyrus ("cap" of Broca), and the hindmost edge of the continuation of this into the external orbital gyrus.

That this is the correct view of the external projection of the insula is confirmed by putting together outlines of Plates 15 and 21, in Professor

Fraser's work. The perspective view of the degree to which the opercula cover the insula is in exact agreement with the foregoing description.

The localization of the individual sulci and gyri on the surface of the insula is greatly assisted by Professor Cunningham's observations on p. 95 of this Memoir, and by the previous descriptions of Eberstaller (p. 96), the sulcus centralis insulæ from its first appearance in development (Cunningham) lies in the line of the fissure of Rolando. Since it bounds posteriorly the pole of the insula, all that is necessary to determine its situation is to continue the line of the fissure of Rolando (for determination of this see p. 323), down across the edge of the operculum, the Sylvian fissure, and the superior temporal gyrus, passing over this obliquely as far as a point which is horizontally opposite the external orbital sulcus.

The sulcus præcentralis insulæ, which, though at first in line with the sulcus præcentralis inferior of the outer surface of the hemisphere, moves forwards at its upper end during development, so as to correspond with the anterior limb of the Sylvian fissure. The postcentral sulcus of the insula lies fairly in line with the intraparietal sulcus on the outer surface. It runs forwards as well as downwards, and consequently follows a very similar course to that of the central sulcus.

The external projection of these on the skull is therefore particularly easy.

Putting aside for the present the conclusions on this point which may properly be drawn from more recent research, the earlier observations of Hefftler must be alluded to.

In Hefftler's drawing (fig. 1, *loc. cit.*), he represents the insula as being covered by the anterior two-thirds of the superior temporal gyrus in its whole breadth, the hinder fourth of the inferior half of the third frontal gyrus, and narrow strips of the lower ends of the central gyri (not reaching to the summits of Eberstaller's transverse sulci), and finally the hindmost limit is placed opposite the lower end of the inferior postcentral gyrus.

Hefftler figures the insula as lying (seen from the *norma verticalis*) partly anteriorly, partly posteriorly, to the coronal fissure, in the respective proportions of 1 to 2 (*i. e.* one-third in front of the suture), the occipital

pole of the insula terminating just in front of (apparently) the genu of the fissure of Rolando.

Laterally, the highest point of the squamous suture corresponds (according to the same observer) with the centre of the insula, *i. e.* in a large number of cases the fissure of Sylvius. Dalton (Series A, Pl. IV.) shows distinctly that in a sagittal section, the plane of which passes through the second frontal gyrus, the hinder end of the island of Reil lies just in front of the intraparietal (? postcentral) sulcus.

According to Féré, the hindmost pole of the insula lies in the vertical plane, through the upper end of the fissure of Rolando and the asterion; but this would correspond with the hinder end of the posterior limb of the fissure of Sylvius, a relation which is not suggested by any other author, and which is certainly not in accord with my own observations directed to this special point.

So far as the relative position of the insula to the character of the skull is concerned, Altoukhoff has found that the insula extends rather further at each pole in dolichocephalics than in brachycephalics. He also confirms the description given above, except that while he gives in one plate the average position of the posterior pole as corresponding with the lower end of the intraparietal sulcus, *i. e.* the lower end of the sulcus postcentralis inferior, in another plate, wherein the characteristics of the skull are compared, he makes this point of the insula extend behind the postcentral sulcus, and almost to the hinder end of the posterior limb of the Sylvian fissure.

Nothing has thus far been said of the relation of the insula to the basal ganglia. In antero-posterior direction there is no question but that the insula is limited in close parallelism with the lenticular nucleus, and consequently that it does not come into any relation with, as has been suggested, the optic thalamus.

BIBLIOGRAPHY.

Since, for the reasons before stated, it is not possible to directly compare together the results of many authors who have made researches on this subject, reference is directed to the original Papers, most of which are contained in the following list.

For methods consult specially:—Altoukhoff, Anderson, and Makins, Broca, Cunningham, Debierre, Féré, Fraser, Giacomini, Hare, Hefftler, Le Fort, Mies, Müller, Poirier, Reid, Sernoff, Turner.

For Russian Papers see the references at the end of Altoukhoff's Paper.

Altoukhoff [1891]:
"Encephalometrical investigations of the human brain in connexion with sex, age, and a guide of the Skull." Moskow (in Russian).

Anderson and Makins [1889]:
Cranio-cerebral Topography. (Lancet, 13th July, p. 61.)

Bischoff [1886]:
Die Grosshirnwinddungen des Menschen. Munchen.
Abhandlungen der K. Bayerisch Akad. der Wiss. 10 Band. II Abth.

Broca [1861]:
Bullet. de la Soc. Anat.
Instructions Craniologiques Paris, 1875.
Revue d' Anthropologie, 1876.

Broca and Sebileau [1888]:
Chirurgie cranio-cérébrale. Gas des hop. No. 75.

Ceccherelli [1885]:
Annali univ. di. med. E. Chir. April, June. Refer. in Centralblatt f. Chir. 1886. Heft. 1.

Dalton [1885]:

Topographical Anatomy of the Brain. Philadelphia, Lea Bros.

Dana [1889]:

A note on the means of topographical diagnosis of focal disease affecting the so-called motor region of the cerebral cortex. Med. Rec. No. 2.

Debierre [1890]:

S. Verhandlungen des X. internat. med. Congress. Bd. II., s. 49. See also René-Léon Le Fort, p. 62.

Ecker [1876]:

Die topograph. Beziehungen zwischen Schädel und Gehirn.

Archiv. f. Anthropol. Bd. IX., X., p. 62.

Féré:

Bullet. de la Soc. Anat. 1875 and 1877.

Revue d' Anthropologie, 1879.

Contribution a l'etude de la topographie cranio-cerebrale chez quelques singes.

Journal de l' anatomie et de la Physiologie, 1882–1891.

Foulhouze (de la) [1876]:

Recherches sur les Rapports anatomiques du cerveau avec la voute du crane. Thése, Paris.

Fraser [1890]:

Brit. Med. Journ., 8th February.

Also: A guide to operations on the brain. London: Churchill, 1891.

Hamy [1872]:

Revue d' Anthropologie, p. 424.

Hare:

Journal of Anatomy and Physiology, vol. xviii., p. 174.

See also: Byrom Bramwell, Cerebral Tumours.

Heftler [1873]:

Ueber die Beziehungen der Hirnwindungen zum Schädel beim Menschen. Dissert. St. Petersburg.

See also: Beiträge zur Anatomie und Histologie. Herausgeben von Dr. Th. Landzert. St. Petersburg, 1878.

Le Fort [1890]:

La topographie cranio-cérébrale, applications chirurgicales. Paris and Lille.

Mies [1890]:

Instrument zur Bestimmung correspondirender Punkte auf Kopf, Schädel und Gehirn. X. Internat. med. Congress, Abtheil. f. Psychiatrie.

Müller [1889]:
Ueber die Topographischen Beziehungen des Hirns zum Schädeldach. Bern: Schmidt, Francke & Cie.

Paris (Charles) [1876]:
Indications de la trépanation des os du crâne au point de vue de la localisation cerébrale. Thèse de Paris. Juillet.

Passet [1882]:
Ueber einige unterschiede des Grosshirns dem nach Geschlecht. Archiv für Anthropologie. Band 14, p. 89.

Poirier [1891]:
Topographie cranio-encéphalique, Trepanation. Paris.

Pozzi [1887]:
Archives Generales de Medicine, p. 442.

Reid [1884]:
'Lancet,' II., p. 539.

Rieger [1885]:
Eine exacte Methode der Craniographie. Jena.

Seligmuller:
Archiv f. Psych. Bd. VIII.

Sernoff [1889]:
Encephalometer. An apparatus for the determination of the arrangement of the several parts of the human brain in the living body. Preliminary communication. (In Russian: see Altoukhoff.)

Turner [1873–1874]:
Journal of Anatomy and Physiology, vol. viii., pp. 142, 359.

Wilson (Chiene) [1888]:
Lancet, March 3. See also Byrom Bramwell: Cerebral Tumours.

EXPLANATION OF PLATES I. TO VIII.

PLATE I.

[A series of Views of the Cerebrum of the Human Fœtus at different stages of development. The various figures were drawn upon the stone from photographs.]

LETTERING COMMON TO ALL THE FIGURES.

$f.^1$	Sulcus frontalis primus.
$f.^2$	Sulcus frontalis secundus.
f. m.	Sulcus frontalis medius.
p. c.	Early sulcus præcentralis inferior.
p. c. i.	Sulcus præcentralis inferior.
p. c. s.	Sulcus præcentralis superior.
r.	Fissure of Rolando.
$r.^1$	Lower piece of the fissure of Rolando.
$r.^2$	Upper piece of the fissure of Rolando.
p.	Intraparietal sulcus.
$p.^1$	Sulcus postcentralis inferior.
$p.^2$	Sulcus postcentralis superior.
$p.^3$	Ramus horizontalis of the intraparietal sulcus.
$p.^4$	Ramus occipitalis of the intraparietal sulcus.
e. p.	Fissura perpendicularis externa.
e. c.	External calcarine fissure.
f. a.	Fissura arcuata.

[N.B.—In Figures 11, 14, and 24 the dotted outlines indicate in each case the area of cerebral surface covered by the parietal bone.]

Figure 1.—Outer surface of the cerebrum of a fœtus which had probably reached the tenth or eleventh week of development. (Specimen in the Museum of University College, London.)

Figures 2 and 3.—Two different views of the cerebrum of a fœtus which had apparently reached a stage of development corresponding to the eleventh week. (Specimen in the Museum of University College, London.) In Figure 3 a curious projection from the hinder end of the right hemisphere (*a*) is seen. (*Vide* p. 25 of the text.)

Figures 4 and 5.—The two hemispheres of the cerebrum of a fœtus in the twelfth week of development:—*p. o.* precursor of the parieto-occipital fissure; *c.* precursor of the calcarine fissure.

Figures 6, 7 and 8.—Different views of the cerebrum of a fœtus preserved in the Museum of University College, London; period of development, twelfth week:—*b.*, transitory fissure in the ground of the future Sylvian fissure.

Figures 9 and 10.—Different views of a fœtal cerebrum preserved in the Biological Museum of the University of Oxford. Period of development, twelfth week. The figures were drawn on the stone from photographs supplied by Professor Victor Horsley. The cerebrum in each case is represented somewhat larger than it is in reality.

Figures 11 and 12.—The external and mesial surfaces of the left hemisphere of a fœtal cerebrum in the early part of the fourth month of development—say, the thirteenth week:—*f.*, transitory fissure; *e.*, anterior part of the fissura arcuata; *f. a.*, fissura arcuata; *d.*, radial transitory fissure; *p. o.*, precursor of the parieto-occipital fissure; *e. c.*, external calcarine fissure; *c.*, precursor of the calcarine fissure; *h.*, hippocampal fissure.

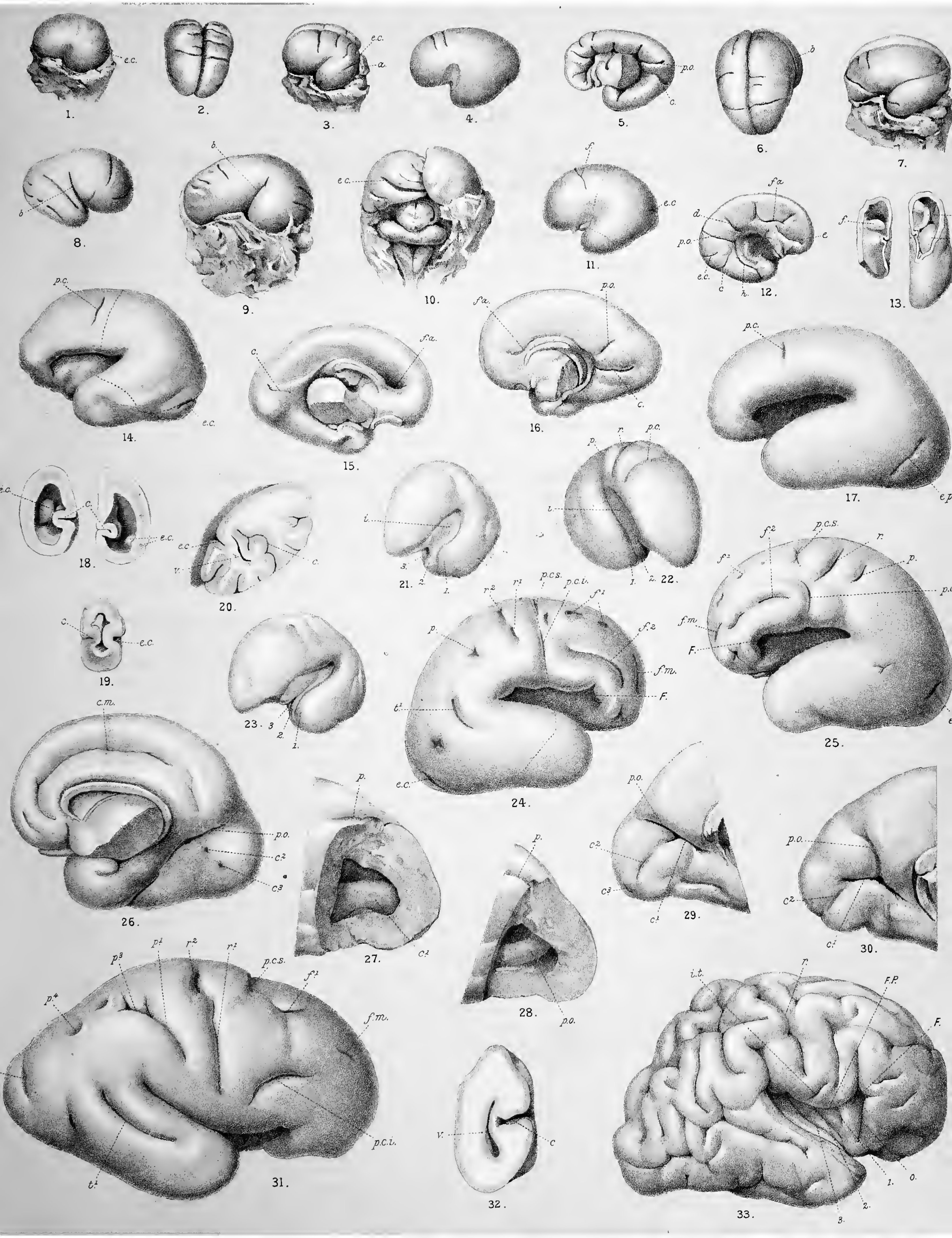
Figure 13.—The opposite hemisphere to that represented in Figures 11 and 12, with the roof of the cerebral cavity removed:—*f.*, infolding produced by the fissure marked *f.* in Figure 11; *f. a.*, infolding corresponding to the main part of the fissura arcuata; *c. s.*, corpus striatum.

Figures 14 and 15.—Outer and mesial surfaces of a left fœtal hemisphere in the early part of the fifth month of development:—*c.*, calcarine fissure.

Figure 16.—Mesial face of a right fœtal hemisphere (same brain as Figures 14 and 15) in the early part of the fifth month of development:—*p. o.*, parieto-occipital fissure; *c.*, calcarine fissure.

Figure 17.—Outer surface of a left cerebral hemisphere (considerably enlarged) in the early part of the fifth month of development. The specimen is preserved in the Biological Museum of the Oxford University. Photograph obtained from Professor Victor Horsley.

Figure 18.—The occipital extremities of two hemispheres of a brain in the early part of the fifth month of development removed by a coronal section. The portions removed are viewed from the front. The cavity of the posterior ventricular horn is seen, and also the intraventricular projections into it, caused by the external calcarine (*e. c.*) and calcarine (*c.*) fissures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p.
p.c
f.m
F.
26.
c.m.
p.o.
c²
c³
27.
p.
c¹
28.
p.
p.o.
29.
p.o.
c²
c³
c¹
30.
p.o.
c²
c¹
31.
p³
p¹
r²
r¹
p.c.s.
f¹
p⁴
f.m.
p.c.i.
t¹
32.
v.
c
33.
i.t.
r.
F.P.
F.
1.
0.
2.
3.

PLATE I.—*continued.*

Figure 19.—The posterior part of the hemisphere, represented in Figure 14, removed by coronal section. The intraventricular infoldings produced by the calcarine (*c.*) and external calcarine (*e. c.*) fissures are seen.

Figure 20.—The posterior part of the right cerebral hemisphere of *Cercopithecus griseoviridis*, removed by coronal section. The effect produced upon the posterior horn of the lateral ventricle (*v.*) by the calcarine (*c.*) and external calcarine fissures is seen.

Figure 21.—Left cerebral hemisphere viewed from the front. Period of development, middle of fifth month:—*i.*, fossa Sylvii; 1 and 2, primitive polar gyri (*vide* 102 of the text); 3, the uncus.

Figure 22.—Right cerebral hemisphere in the sixth month of development:—1 and 2, primitive polar gyri.

Figure 23.—Left cerebral hemisphere in the fifth month of development:—1 and 2, primitive polar gyri; 3. the uncus.

Figures 24 and 25.—The two cerebral hemispheres from a fœtus which had reached the latter part of the sixth month of development:—*t.*, parallel sulcus; *o.*, the first appearance of the frontal operculum (pars triangularis).

Figure 26.—The inner face of the hemisphere represented in Figure 24:—*c. m.*, calloso-marginal sulcus; *p. o.*, parieto-occipital fissure conjoined with the "stem" of the calcarine fissure; $c.^1$ and $c.^2$, two punctiform depressions representing the earliest condition of the two parts of the secondary posterior part of the calcarine fissure.

[N.B.—In this figure, $c.^1$ should have been lettered $c.^3$ to bring it into correspondence with the lettering in the other figures.]

Figures 28 and 29.—Two views of the hinder end of a cerebrum obtained from a fœtus in the early part of the seventh month.

In Figure 29 the mesial face of the hemisphere is represented. The parieto-occipital fissure (*p. o.*) joined to the "stem" of the calcarine fissure ($c.^1$) is exhibited. The two shallow secondary sulci ($c.^2$ and $c.^3$), which afterwards unite to form the posterior part of the calcarine fissure, are also seen.

In Figure 28 the outer face of the same portion of this hemisphere is exhibited, and the outer wall of the ventricular cavity has been removed. The intraventricular infolding corresponding to the united parieto-occipital and anterior calcarine fissures is observed (*p. o.*). In this case the parieto-occipital fissure forms a very decided infolding.

Figures 27 and 30.—Two views of the hinder end of a cerebrum obtained from a fœtus in the early part of the seventh month. Figure 30, mesial surface; Figure 27, outer surface with the outer wall of the ventricular cavity removed. Lettering the same as in Figures 28 and 29. In this case the parieto-occipital fissure produces no intraventricular elevation; the calcar avis is entirely formed by the "stem" or the anterior complete part of the calcarine fissure. (*Vide* p. 51 of the text.)

Figure 31.—Outer surface of a cerebral hemisphere in the early part of the seventh month of development; considerably enlarged. The specimen is in the Biological Museum of the University of Oxford. The photograph was obtained from Professor Victor Horsley:—$t.^1$, parallel sulcus; *p. c. i.*, in all probability this sulcus is the inferior frontal furrow, or the inferior frontal furrow in conjunction with the sulcus præcentralis inferior.

Figure 32.—Coronal section through the hinder end of a cerebral hemisphere in the seventh month of development, to show the relation of the "stem" of the calcarine fissure (*c.*) to the ventricular cavity (*v.*).

Figure 33.—Fœtal hemisphere well on in the eighth month of development. The temporal operculum has been removed. The three radial furrows on the island of Reil—the sulcus præcentralis 1, the sulcus centralis 2, and the sulcus postcentralis 3 are exhibited:—*i. t.*, inferior transverse furrow of the fissure of Rolando; *F. P.*, fronto-parietal operculum; *O.*, orbital operculum. The pars triangularis or frontal operculum is well seen, but it is not lettered.

PLATE II.

[A series of Views of the Cerebrum of the Human Fœtus at different periods of development. The various figures were drawn upon the stone from photographs.]

LETTERING COMMON TO ALL THE FIGURES.

$f.^1$ . .	Sulcus frontalis primus.
$f.^2$ . .	Sulcus frontalis secundus.
f. m. .	Sulcus frontalis medius.
p. c. . .	Early sulcus præcentralis inferior.
p. c. i. .	Sulcus præcentralis inferior.
p. c. s. .	Sulcus præcentralis superior.
F. P. .	Fronto-parietal operculum.
F. . .	Frontal operculum (pars triangularis).
O. . .	Orbital operculum.
r. . .	Fissure of Rolando.
$r.^1$ . .	Upper piece of the fissure of Rolando.
$r.^2$ . .	Lower piece of the fissure of Rolando.
p. . .	Intraparietal sulcus.
$p.^1$ . .	Sulcus postcentralis inferior.
$p.^2$ . .	Sulcus postcentralis superior.
$p.^3$ . .	Ramus horizontalis of the intraparietal sulcus.
$p.^4$ . .	Ramus occipitalis of the intraparietal sulcus.
e. p. . .	Fissura perpendicularis externa.
e. c. . .	External calcarine fissure.
$t.^1$ . .	Parallel sulcus.
$t.^2$ . .	Second temporal sulcus.

[N.B.—In Figures 5, 9, 11, 15, 18, and 20 the dotted outlines in each case indicate the area of cerebral surface covered by the parietal bone.]

Figure 1.—Fœtus in the tenth or eleventh week of development, with the cerebrum exposed *in situ.*

Figure 2.—Right hemisphere of a cerebrum from a fœtus in the tenth week of development.

Figure 3.—Left hemisphere of a cerebrum from a fœtus in the twelfth week of development.

Figure 4.—Left hemisphere of a cerebrum from a fœtus in the twelfth week of development:—2, the primitive polar gyrus formed by the insula posterior.

Figure 5.—Right hemisphere of a cerebrum from a fœtus in the first half of the fourth month of development.

Figure 6.—Left hemisphere of a fœtal cerebrum in the latter part of the fourth month of development.

Figure 7.—Right hemisphere of a fœtal cerebrum in the early part of the fifth month of development:—1 and 2, primitive polar gyri. (*Vide* p. 102 of the text.)

Figures 8 and 9.—The two hemispheres of a cerebrum taken from a fœtus which had apparently reached the second week of the fifth month of development.

Figure 10.—Right cerebral hemisphere from a fœtus which had probably reached the sixth month of development:—2, sulcus centralis insulæ.

Figure 11.—Left cerebral hemisphere of a fœtus at the end of the fifth month of development.

Figures 12 to 15.—Four cerebral hemispheres from female twins which had apparently reached the early part of the sixth month of development:—1, sulcus præcentralis insulæ; 2, sulcus centralis insulæ.

Figure 16.—Right hemisphere of a fœtal cerebrum in the early part of the sixth month of development.

Figures 17 and 18.—The two hemispheres of a cerebrum in the early part of the seventh month of development:—1, sulcus præcentralis insulæ; 2, sulcus centralis insulæ.

Figures 19 and 20.—The two hemispheres of a cerebrum in the early part of the seventh month of development:—1, sulcus præcentralis insulæ; 2, sulcus centralis insulæ.

Figure 21.—Left cerebral hemisphere in the end of the sixth or the beginning of the seventh month of development.

Note the development of the hinder transverse gyrus of Heschl (*h.*), and in connexion with this the terminal bifurcation of the posterior horizontal branch of the Sylvian fissure. (*Vide* Eberstaller's remarks upon this, in his article entitled "Zur Oberflächen-Anatomie der Grosshirn-Hemisphären," Wiener Medizinische Blätter. No. 20, 1884, p. 613.)

Figures 22 and 23.—The two hemispheres of a cerebrum in the early part of the sixth month of development:—1 and 2, primitive polar gyri (*vide* p. 102 of the text); 3, the uncus.

Figure 24.—Left cerebral hemisphere in the seventh month of development.

Figures 25 and 26.—The two hemispheres of a cerebrum in the last week of the fifth month of development.

EXPLANATION OF PLATES I. TO VIII.

PLATE I.

[A series of Views of the Cerebrum of the Human Fœtus at different stages of development. The various figures were drawn upon the stone from photographs.]

LETTERING COMMON TO ALL THE FIGURES.

$f.^1$	Sulcus frontalis primus.	$p.$	Intraparietal sulcus.
$f.^2$	Sulcus frontalis secundus.	$p.^1$	Sulcus postcentralis inferior.
f. m.	Sulcus frontalis medius.	$p.^2$	Sulcus postcentralis superior.
p. c.	Early sulcus præcentralis inferior.	$p.^3$	Ramus horizontalis of the intraparietal sulcus.
p c. i.	Sulcus præcentralis inferior.	$p.^4$	Ramus occipitalis of the intraparietal sulcus.
p. c. s.	Sulcus præcentralis superior.	*e. p.*	Fissura perpendicularis externa.
r.	Fissure of Rolando.	*e. c.*	External calcarine fissure.
$r.^1$	Lower piece of the fissure of Rolando.	*f. a.*	Fissura arcuata.
$r.^2$	Upper piece of the fissure of Rolando.		

[N.B.—In Figures 11, 14, and 24 the dotted outlines indicate in each case the area of cerebral surface covered by the parietal bone.]

Figure 1.—Outer surface of the cerebrum of a fœtus which had probably reached the tenth or eleventh week of development. (Specimen in the Museum of University College, London.)

Figures 2 and 3.—Two different views of the cerebrum of a fœtus which had apparently reached a stage of development corresponding to the eleventh week. (Specimen in the Museum of University College, London.) In Figure 3 a curious projection from the hinder end of the right hemisphere (*a*) is seen. (*Vide* p. 25 of the text.)

Figures 4 and 5.—The two hemispheres of the cerebrum of a fœtus in the twelfth week of development:—*p. o.* precursor of the parieto-occipital fissure; *c.* precursor of the calcarine fissure.

Figures 6, 7 and 8.—Different views of the cerebrum of a fœtus preserved in the Museum of University College, London; period of development, twelfth week:—*b.*, transitory fissure in the ground of the future Sylvian fissure.

Figures 9 and 10.—Different views of a fœtal cerebrum preserved in the Biological Museum of the University of Oxford. Period of development, twelfth week. The figures were drawn on the stone from photographs supplied by Professor Victor Horsley. The cerebrum in each case is represented somewhat larger than it is in reality.

Figures 11 and 12.—The external and mesial surfaces of the left hemisphere of a fœtal cerebrum in the early part of the fourth month of development—say, the thirteenth week:—*f.*, transitory fissure; *e.*, anterior part of the fissura arcuata; *f. a.*, fissura arcuata; *d.*, radial transitory fissure; *p. o.*, precursor of the parieto-occipital fissure; *e. c.*, external calcarine fissure; *c.*, precursor of the calcarine fissure; *h.*, hippocampal fissure.

Figure 13.—The opposite hemisphere to that represented in Figures 11 and 12, with the roof of the cerebral cavity removed:—*f.*, infolding produced by the fissure marked *f.* in Figure 11; *f. a.*, infolding corresponding to the main part of the fissura arcuata; *c. s.*, corpus striatum.

Figures 14 and 15.—Outer and mesial surfaces of a left fœtal hemisphere in the early part of the fifth month of development:—*c.*, calcarine fissure.

Figure 16.—Mesial face of a right fœtal hemisphere (same brain as Figures 14 and 15) in the early part of the fifth month of development:—*p. o.*, parieto-occipital fissure; *c.*, calcarine fissure.

Figure 17.—Outer surface of a left cerebral hemisphere (considerably enlarged) in the early part of the fifth month of development. The specimen is preserved in the Biological Museum of the Oxford University. Photograph obtained from Professor Victor Horsley.

Figure 18.—The occipital extremities of two hemispheres of a brain in the early part of the fifth month of development removed by a coronal section. The portions removed are viewed from the front. The cavity of the posterior ventricular horn is seen, and also the intraventricular projections into it, caused by the external calcarine (*e. c.*) and calcarine (*c.*) fissures

1.
e.c.
2.
3.
e.c.
a.
4.
5.
p.o.
c
6.
b
7.
8.
b.
9.
b
10.
e.c.
11.
f.
e.c.
12.
f.a.
d.
p.o.
c
e.c.
c
h.
13.
f.
14.
p.c.
e.c.
15.
c.
f.a.
16.
f.a.
p.o.
c
17.
p.c.
18.
e.c
c.
e.c.
19.
c.
e.c.
20.
e.c.
v.
c.
21.
i.
3.
2.
1.
22.
p.
r.
p.c.
i.
1.
2.
23.
3
2.
1.
24.
r2
r1
p.c.s.
p.c.i.
f1
f.2
f.m.
F.
p.
t1
e.c.
25.
f2
p.c.s.
r.
p.
f1
f.m.
F.
26.
c.m.
p.o.
c2
c3
27.
p.
c1
28.
p.
p.o.
29.
p.o.
c2
c3
c1
30.
p.o.
c2
c1
31.
p3
p1
r2
r1
p.c.s.
f1
p4
f.m.
e.p.
p.c.i.
t1
32.
V.
c
33.
i.t.
r.
F.P.
1.
2.
3.
o.

PLATE I.—*continued.*

Figure 19.—The posterior part of the hemisphere, represented in Figure 14, removed by coronal section. The intraventricular infoldings produced by the calcarine (*c.*) and external calcarine (*e. c.*) fissures are seen.

Figure 20.—The posterior part of the right cerebral hemisphere of *Cercopithecus griseoviridis*, removed by coronal section. The effect produced upon the posterior horn of the lateral ventricle (*v.*) by the calcarine (*c.*) and external calcarine fissures is seen.

Figure 21.—Left cerebral hemisphere viewed from the front. Period of development, middle of fifth month:—*i.*, fossa Sylvii; 1 and 2, primitive polar gyri (*vide* 102 of the text); 3, the uncus.

Figure 22.—Right cerebral hemisphere in the sixth month of development:—1 and 2, primitive polar gyri.

Figure 23.—Left cerebral hemisphere in the fifth month of development:—1 and 2, primitive polar gyri; 3. the uncus.

Figures 24 and 25.—The two cerebral hemispheres from a fœtus which had reached the latter part of the sixth month of development:—*t.*, parallel sulcus; *o.*, the first appearance of the frontal operculum (pars triangularis).

Figure 26.—The inner face of the hemisphere represented in Figure 24:—*c. m.*, calloso-marginal sulcus; *p. o.*, parieto-occipital fissure conjoined with the "stem" of the calcarine fissure; $c.^1$ and $c.^2$, two punctiform depressions representing the earliest condition of the two parts of the secondary posterior part of the calcarine fissure.

[N.B.—In this figure, $c.^1$ should have been lettered $c.^3$ to bring it into correspondence with the lettering in the other figures.]

Figures 28 and 29.—Two views of the hinder end of a cerebrum obtained from a fœtus in the early part of the seventh month.

In Figure 29 the mesial face of the hemisphere is represented. The parieto-occipital fissure (*p. o.*) joined to the "stem" of the calcarine fissure ($c.^1$) is exhibited. The two shallow secondary sulci ($c.^2$ and $c.^3$), which afterwards unite to form the posterior part of the calcarine fissure, are also seen.

In Figure 28 the outer face of the same portion of this hemisphere is exhibited, and the outer wall of the ventricular cavity has been removed. The intraventricular infolding corresponding to the united parieto-occipital and anterior calcarine fissures is observed (*p. o.*). In this case the parieto-occipital fissure forms a very decided infolding.

Figures 27 and 30.—Two views of the hinder end of a cerebrum obtained from a fœtus in the early part of the seventh month. Figure 30, mesial surface; Figure 27, outer surface with the outer wall of the ventricular cavity removed. Lettering the same as in Figures 28 and 29. In this case the parieto-occipital fissure produces no intraventricular elevation; the calcar avis is entirely formed by the "stem" or the anterior complete part of the calcarine fissure. (*Vide* p. 51 of the text.)

Figure 31.—Outer surface of a cerebral hemisphere in the early part of the seventh month of development; considerably enlarged. The specimen is in the Biological Museum of the University of Oxford. The photograph was obtained from Professor Victor Horsley:—$t.^1$, parallel sulcus; *p. c. i.*, in all probability this sulcus is the inferior frontal furrow, or the inferior frontal furrow in conjunction with the sulcus præcentralis inferior.

Figure 32.—Coronal section through the hinder end of a cerebral hemisphere in the seventh month of development, to show the relation of the "stem" of the calcarine fissure (*c.*) to the ventricular cavity (*v.*).

Figure 33.—Fœtal hemisphere well on in the eighth month of development. The temporal operculum has been removed. The three radial furrows on the island of Reil—the sulcus præcentralis 1, the sulcus centralis 2, and the sulcus postcentralis 3 are exhibited:—*i. t.*, inferior transverse furrow of the fissure of Rolando; *F. P.*, fronto-parietal operculum; *O.*, orbital operculum. The pars triangularis or frontal operculum is well seen, but it is not lettered.

PLATE II.

[A series of Views of the Cerebrum of the Human Fœtus at different periods of development. The various figures were drawn upon the stone from photographs.]

LETTERING COMMON TO ALL THE FIGURES.

f.[1]	Sulcus frontalis primus.
f.[2]	Sulcus frontalis secundus.
f. m.	Sulcus frontalis medius.
p. c.	Early sulcus præcentralis inferior.
p. c. i.	Sulcus præcentralis inferior.
p. c. s.	Sulcus præcentralis superior.
F. P.	Fronto-parietal operculum.
F.	Frontal operculum (pars triangularis).
O.	Orbital operculum.
r.	Fissure of Rolando.
r.[1]	Upper piece of the fissure of Rolando.
r.[2]	Lower piece of the fissure of Rolando.
p.	Intraparietal sulcus.
p.[1]	Sulcus postcentralis inferior.
p.[2]	Sulcus postcentralis superior.
p.[3]	Ramus horizontalis of the intraparietal sulcus.
p.[4]	Ramus occipitalis of the intraparietal sulcus.
e. p.	Fissura perpendicularis externa. of Bischoff
e. c.	External calcarine fissure.
t.[1]	Parallel sulcus.
t.[2]	Second temporal sulcus.

[N.B.—In Figures 5, 9, 11, 15, 18, and 20 the dotted outlines in each case indicate the area of cerebral surface covered by the parietal bone.]

Figure 1.—Fœtus in the tenth or eleventh week of development, with the cerebrum exposed *in situ*.

Figure 2.—Right hemisphere of a cerebrum from a fœtus in the tenth week of development.

Figure 3.—Left hemisphere of a cerebrum from a fœtus in the twelfth week of development.

Figure 4.—Left hemisphere of a cerebrum from a fœtus in the twelfth week of development:—2, the primitive polar gyrus formed by the insula posterior.

Figure 5.—Right hemisphere of a cerebrum from a fœtus in the first half of the fourth month of development.

Figure 6.—Left hemisphere of a fœtal cerebrum in the latter part of the fourth month of development.

Figure 7.—Right hemisphere of a fœtal cerebrum in the early part of the fifth month of development:—1 and 2, primitive polar gyri. (*Vide* p. 102 of the text.)

Figures 8 and 9.—The two hemispheres of a cerebrum taken from a fœtus which had apparently reached the second week of the fifth month of development.

Figure 10.—Right cerebral hemisphere from a fœtus which had probably reached the sixth month of development:—2, sulcus centralis insulæ.

Figure 11.—Left cerebral hemisphere of a fœtus at the end of the fifth month of development.

Figures 12 to 15.—Four cerebral hemispheres from female twins which had apparently reached the early part of the sixth month of development:—1, sulcus præcentralis insulæ; 2, sulcus centralis insulæ.

Figure 16.—Right hemisphere of a fœtal cerebrum in the early part of the sixth month of development.

Figures 17 and 18.—The two hemispheres of a cerebrum in the early part of the seventh month of development:—1, sulcus præcentralis insulæ; 2, sulcus centralis insulæ.

Figures 19 and 20.—The two hemispheres of a cerebrum in the early part of the seventh month of development:—1, sulcus præcentralis insulæ; 2, sulcus centralis insulæ.

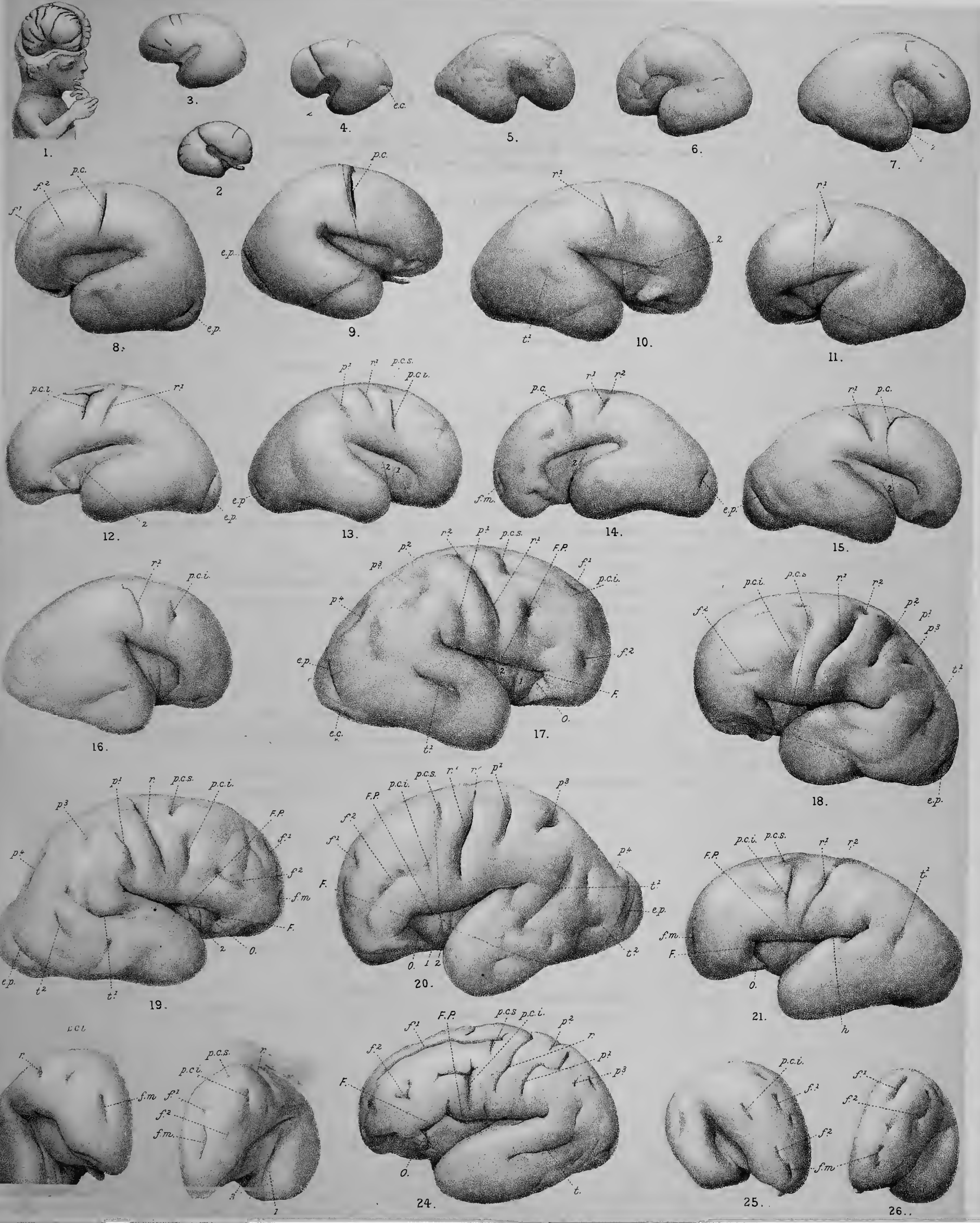
Figure 21.—Left cerebral hemisphere in the end of the sixth or the beginning of the seventh month of development.

Note the development of the hinder transverse gyrus of Heschl (*h.*), and in connexion with this the terminal bifurcation of the posterior horizontal branch of the Sylvian fissure. (*Vide* Eberstaller's remarks upon this, in his article entitled "Zur Oberflächen-Anatomie der Grosshirn-Hemisphären," Wiener Medizinische Blätter. No. 20, 1884, p. 613.)

Figures 22 and 23.—The two hemispheres of a cerebrum in the early part of the sixth month of development:—1 and 2, primitive polar gyri (*vide* p. 102 of the text); 3, the uncus.

Figure 24.—Left cerebral hemisphere in the seventh month of development.

Figures 25 and 26.—The two hemispheres of a cerebrum in the last week of the fifth month of development.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6.
c.m.
c.[1]
c.[2]
c.[3]
c.l.
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PLATE III.

[The Mesial Face of the Cerebral Hemisphere of the Human Fœtus at different stages of development. The various figures were drawn on the stone from photographs.]

LETTERING COMMON TO ALL THE FIGURES.

f. a. a. . . Fissura arcuata anterior.
f. a. p. . . Fissura arcuata posterior.
c. m. . Calloso-marginal sulcus.
c. . . . Calcarine fissure.
$c.^1$ . . The "stem" of the calcarine fissure or the anterior calcarine fissure.
$c.^2$ . . The fore piece of the secondary posterior calcarine sulcus.
$c.^3$ . . The hinder piece of the secondary posterior calcarine sulcus.
p. o. . . The parieto-occipital fissure.
c. l. . . Collateral fissure.

Figures 1 and 2.—The two cerebral hemispheres from a fœtus in the twelfth week of development.

Figures 3 and 4.—The two cerebral hemispheres from a fœtus in the first half of the fourth month of development: probably the fourteenth week.

Figures 5 and 6.—The two cerebral hemispheres from a fœtus in the second half of the fourth month of development (fifteenth or sixteenth week).

Figures 7 and 8.—The two cerebral hemispheres from a fœtus in the early part of the fifth month of development.

Figures 9 and 10.—The two cerebral hemispheres from a fœtus in the middle of the fifth month of development.

Figure 11.—The right cerebral hemisphere from a fœtus in the early part of the fifth month of development.

Figure 12.—The left cerebral hemisphere from a fœtus in the latter part of the fifth month of development.

Figure 13.—The right cerebral hemisphere from a fœtus in the beginning of the sixth month of development.

Figures 14 and 15.—The two cerebral hemispheres from a fœtus approaching the middle of the fifth month of development.

Figures 16 to 19.—The four cerebral hemispheres of two female fœtal twins in the early part of the sixth month of development. They represent the mesial aspect of the same hemispheres which are figured in Plate II. (Figures 12 to 15.)

Note that in Figure 19 the letter "$c.^1$" should be "$c.^2$"

Figures 20 and 21.—The two cerebral hemispheres from a fœtus at the end of the fifth month of development.

Figure 22.—The left cerebral hemisphere of a fœtus in the early part of the sixth month of development.

Figure 23.—The right cerebral hemisphere of a fœtus in the middle of the sixth month of development.

Figure 24.—Right cerebral hemisphere in the first week of the sixth month of development.

Figures 25 and 26.—The two cerebral hemispheres from a fœtus in the beginning of the seventh month of development.

Figures 27 and 28.—The two cerebral hemispheres of a fœtus in the early part of the seventh month of development.

Figure 29.—Right cerebral hemisphere of a fœtus at the end of the sixth month of development.

PLATE IV.

[The various figures in this Plate were drawn on the stone from Photographs.]

LETTERING COMMON TO FIGURES 1, 8, 9, 10 AND 11.

$f.^1$	Sulcus frontalis superior.
$f.^2$ . .	Sulcus frontalis inferior.
f. m.	Sulcus frontalis medius.
c. o.	Sulcus fronto-orbitalis.
p. c. .	Sulcus præcentralis inferior.
p. c. s. .	Sulcus præcentralis superior.
p. c. i.	Sulcus præcentralis inferior.
r. . . .	Fissure of Rolando.
p. . . .	Intraparietal sulcus.
$p.^1$ . .	Sulcus postcentralis inferior.
$p.^2$ . .	Sulcus postcentralis superior.
$p.^3$ . . .	Sulcus horizontalis intraparietalis.
i. p. . . .	Inferior transverse furrow of the intraparietal sulcus.
e. c. . . .	External calcarine fissure.
$t.^1$ . . .	Parallel sulcus.
$t.^2$ . . .	Second temporal sulcus.
S. M. . .	Supramarginal gyrus.
An. . . .	Angular gyrus.
$H.^1$ $H.^2$ $H.^3$	Transverse temporal gyri of Heschl.
R. . . .	Insula.
$A.^1$ . . .	First annectant gyrus (arcus parieto-occipitalis).

LETTERING COMMON TO FIGURES 5, 6 AND 7.

r. . . .	Upper end of the fissure of Rolando.
c. m. . .	Calloso-marginal sulcus.
p. c. .	Præcuneus.
p. o. .	Parieto-occipital fissure.
Cun. . .	Cuneus.
c. . .	Gyrus cunei.
S. . .	"Stem" of the calcarine fissure.
C. and *C.''*	The two parts of the posterior secondary calcarine sulcus.
c. f. . .	Collateral fissure.
g. l. . .	Gyrus lingualis.
c. c. . .	Corpus callosum.
g. f. . .	Gyrus fornicatus.

Figure 1.—The left cerebral hemisphere of a fœtus in the latter part of the eighth month of development. The temporal operculum has been removed so as to expose the insula :—1, sulcus præcentralis insulæ ; 2, sulcus centralis insulæ ; 3, sulcus postcentralis insulæ ; *O.*, orbital operculum ; *F.*, frontal operculum (pars triangularis) ; *F. P.*, fronto-parietal operculum.

Figure 2.—The mesial aspect of the hinder end of a right cerebral hemisphere from a lower ape (Cercopithecus). The inner wall of the posterior horn of the lateral ventricle and the calcar avis have been removed. The deep surface of the outer wall is therefore exposed, and upon it is seen a vertical elevation corresponding to the "Affenspalte" :—*a. s.*, "Affenspalte" ; *e* , eminence on the wall of the ventricle corresponding to it.

Figure 3.—The hinder part of the right cerebral hemisphere taken from a fœtus in the latter part of the sixth month of development. The outer wall of the ventricular cavity has been removed so as to expose the interior:—*p. o.*, elevation corresponding to the parieto-occipital fissure and the stem of the calcarine fissure ; *c. f.*, collateral fissure ; *c. e.*, eminentia collateralis ; *h.*, hippocampus major.

Figure 4.—Section through the temporal lobe of a seventh month human fœtus, to show that the anterior part of the collateral fissure does not produce a bulging of the ventricular wall :—*h.*, hippocampal fissure ; *c. f.*, fore part of the collateral fissure ; *v.*, descending horn of the lateral ventricle.

Figure 5.—Mesial surface of the hinder part of a left adult female cerebrum. The parieto-occipital and the calcarine fissures are widely opened up, so that the interior of each may be studied :—$c.^1$ and $c.^2$, the two parts of the deep gyrus cunei ; *C.*, the fore part of the posterior calcarine sulcus ; *C.''*, the hinder part of the posterior calcarine sulcus ; *a. l.*, anterior deep cuneo-lingual gyrus ; *p. l.*, posterior deep cuneo-lingual gyrus.

Figures 6 and 7.—The hinder portions of two cerebral hemispheres of a full-time human fœtus. The mesial surface of each is depicted, and they both show, in the arrangement of the parieto-occipital and the calcarine fissures, a condition which approximates to that seen in the apes. The gyrus cunei (*c.*) is on the surface, and the "stem" of the calcarine fissure (*S.*) runs upwards for some distance into the cuneus, and ends in a bifurcated extremity.

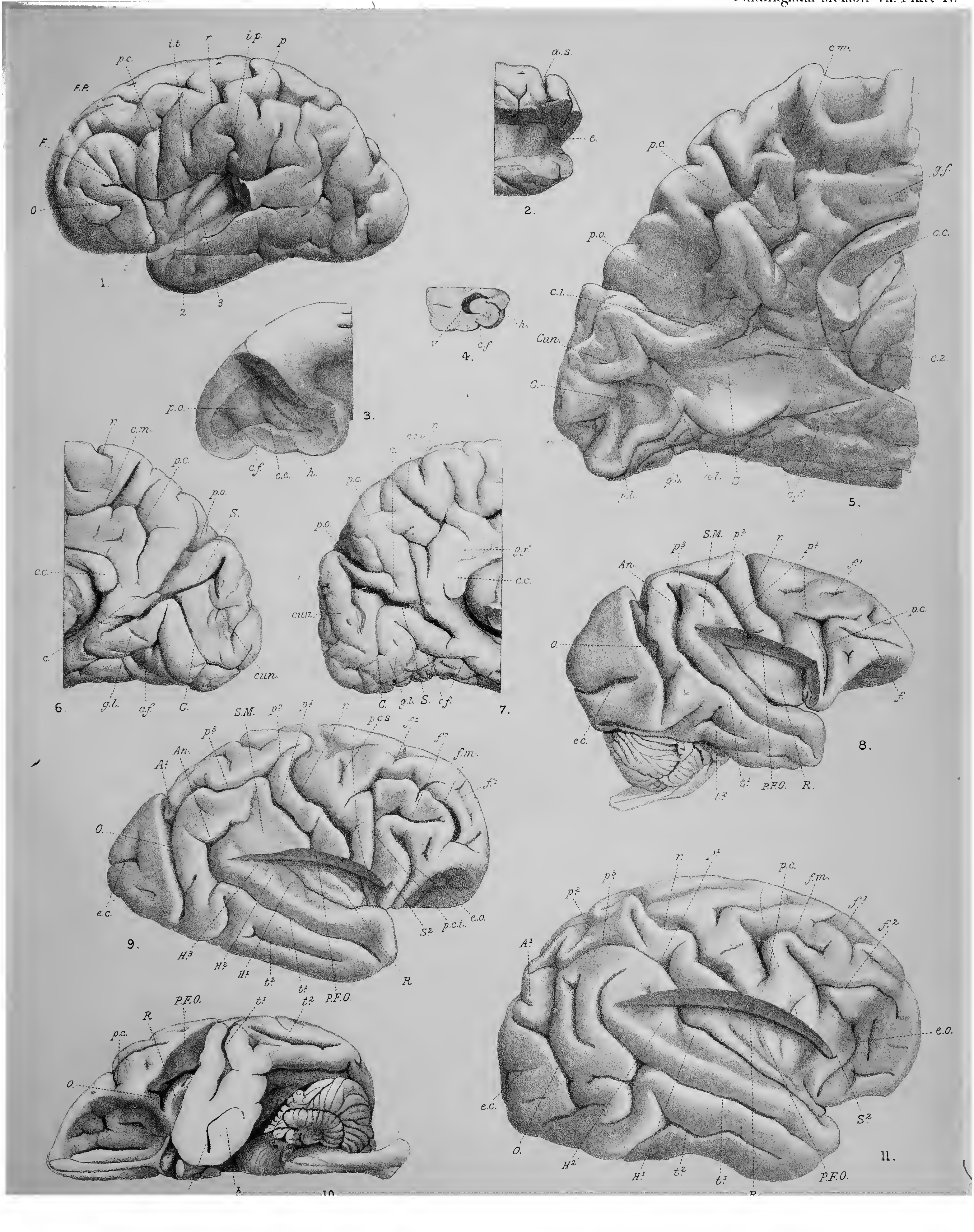
***Figure 8.**—Right cerebral hemisphere of a chacma baboon. The fronto-parietal operculum (*P. F. O.*) has been removed so as to expose the insula :—*o.*, anterior edge of the occipital operculum ; *f.*, inferior frontal furrow.

***Figure 9.**—Right cerebral hemisphere of a young female chimpanzee about three years old. The fronto-parietal operculum (*P. F. O.*) has been removed so as to expose the insula :—$S.^2$, the so-called anterior limb of the Sylvian fissure, in reality the anterior free margin of the fronto-parietal operculum ; *O.*, the anterior edge of the occipital operculum.

Figure 10.—The right cerebral hemisphere of a chacma baboon viewed from below. The anterior end of the temporal lobe has been removed :—*P. F. O.*, lower edge of the fronto-parietal operculum ; *O.*, the small backward projection, which is considered by some anatomists to represent an orbital operculum.

***Figure 11.**—The right cerebral hemisphere of a male orang-utan about six years old. The fronto-parietal operculum (*P. F. O.*) has been removed so as to expose the insula :—$S.^2$, anterior free border of the fronto-parietal operculum (the so-called anterior limb of the fissure of Sylvius) ; *O.*, anterior edge of the occipital operculum.

* The dotted line represents the position of the anterior border of the parietal bone.



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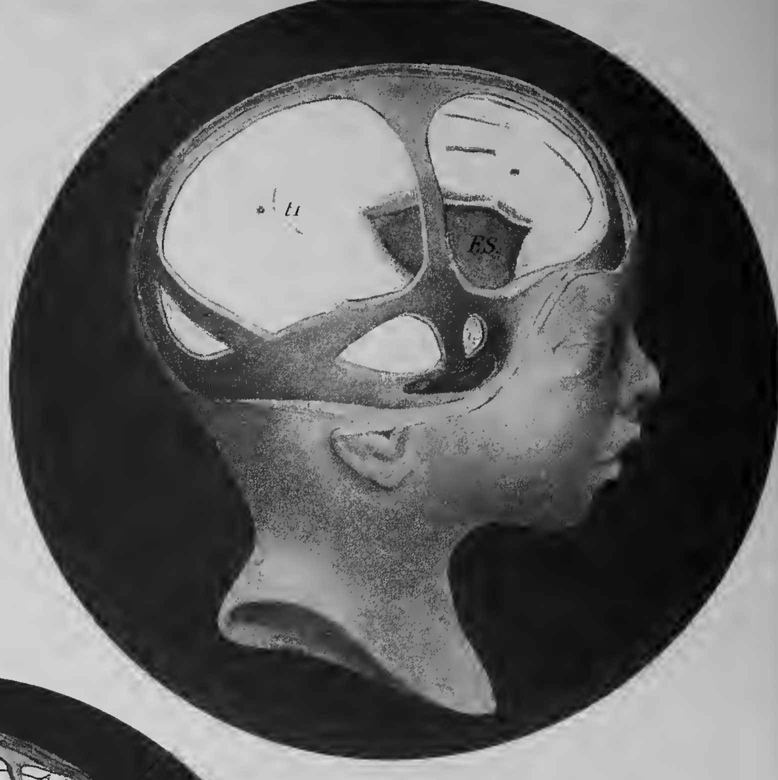
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PLATE V.

[The figures in this Plate were drawn upon the stone from photographs of plaster casts of heads in which the brain is exposed *in situ*. Bars of bone are left along the lines of the sutures, and, in some cases, also along the fore part or the whole length of the temporal ridge.]

Figure 1.—Head of a human fœtus in the early part of the sixth month of development.

Figure 2.—Head of a human fœtus in the early part of the seventh month of development.

Figure 3.—Head of a full-time male human fœtus born by breach-presentation.

Figure 4.—Head of a female infant about twelve months old.

Figure 5.—Head of a female infant about six months old.

LETTERING COMMON TO ALL THE FIGURES.

F.^{1} . . .	Gyrus frontalis primus.
F.^{2} . . .	Gyrus frontalis secundus.
F.^{3} . . .	Gyrus frontalis tertius.
f.^{1} . . .	Sulcus frontalis primus.
f.^{2} . . .	Sulcus frontalis secundus.
f.^{3} . . .	Sulcus frontalis medius (Eberstaller).
f. . . .	(in the apes, Pl. VIII.) sulcus frontalis secundus.
p. c. i. . .	Sulcus præcentralis inferior.
p. c. s. . .	Sulcus præcentralis superior.
r. . . .	Fissure of Rolando.
A. . . .	Gyrus centralis anterior.
B. . . .	Gyrus centralis posterior.
S. M. . .	Gyrus supramarginalis.
An. . .	Gyrus angularis.
P. S. . .	Lobulus parietalis superior.
p. . . .	Sulcus intraparietalis.
p.^{1} . . .	Sulcus postcentralis inferior.
p.^{2} . . .	Sulcus postcentralis superior.
p.^{3} . . .	Ramus horizontalis (of the intraparietal sulcus).
p.^{4} . . .	Ramus occipitalis (of the intraparietal sulcus).
p. o. . .	Fissura parieto-occipitalis.
o.^{2} . . .	Sulcus occipitalis lateralis (Eberstaller).
S.^{1} . . .	Ramus horizontalis posterior of the Sylvian fissure.
S.^{2} . . .	Ramus anterior ascendens of the Sylvian fissure. Except in figures 9, 13, and 15, in which "*S.*^{2}" indicates the sulcus diagonalis.
T.^{1} . . .	Gyrus temporalis superior.
T.^{2} . . .	Gyrus temporalis medius.
T.^{3} . . .	Gyrus temporalis inferior.
t.^{1} . . .	Sulcus temporalis primus (parallel sulcus).
t.^{2} . . .	Sulcus temporalis secundus.
F. S. . .	Fossa Sylvii.
a. s. . .	Anterior free border of the occipital operculum.
e. c. . .	External calcarine fissure.
o., . . .	Fronto-orbital sulcus.

N.B.—A black dot marks the position of the frontal eminence and also of the parietal eminence in several of the figures.

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Figure 5.—Head of a female infant about six months old.

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PLATE VI.

[The figures in this Plate were drawn upon the stone from photographs of plaster casts of heads in which the brain is exposed *in situ*. Bars of bone are left along the lines of the sutures, and, in some cases, also along the fore part or the whole length of the temporal ridge.]

Figure 6.—Head of a female child four years old.

Figure 7.—Head of a male child four years old. (The model from which this drawing was taken is not very satisfactory, as the brain bulged somewhat after removal of the cranial wall.)

Figure 8.—Head of a male child five years old.

Figure 9.—Head of a female child eleven years old.

Figure 10.—Head of a male child twelve and a-half years old.

Figure 11.—Head of a youth fifteen years old.

LETTERING COMMON TO ALL THE FIGURES.

$F.^1$ . . . Gyrus frontalis primus.
$F.^2$ . . Gyrus frontalis secundus.
$F.^3$ . . . Gyrus frontalis tertius.
$f.^1$ . . . Sulcus frontalis primus.
$f.^2$ . . . Sulcus frontalis secundus.
$f.^3$ . . . Sulcus frontalis medius (Eberstaller).
f. . . . (in the apes, Pl. VIII.) sulcus frontalis secundus.
p. c. i. . . Sulcus præcentralis inferior.
p. c. s. . . Sulcus præcentralis superior.
r. . . . Fissure of Rolando.
A. . . . Gyrus centralis anterior.
B. . . . Gyrus centralis posterior.
S. M. . . Gyrus supramarginalis.
An. . . Gyrus angularis.
P. S. . . Lobulus parietalis superior.
p. . . . Sulcus intraparietalis.
$p.^1$ . . Sulcus postcentralis inferior.
$p.^2$ . . . Sulcus postcentralis superior.
$p.^3$ . . . Ramus horizontalis (of the intraparietal sulcus).
$p.^4$ . . . Ramus occipitalis (of the intraparietal sulcus).
p. o. . . Fissura parieto-occipitalis.
$o.^2$ . . Sulcus occipitalis lateralis (Eberstaller).
$S.^1$ . . Ramus horizontalis posterior of the Sylvian fissure.
$S.^2$ . . . Ramus anterior ascendens of the Sylvian fissure. Except in figures 9, 13, and 15, in which "$S.^2$" indicates the sulcus diagonalis.
$T.^1$ . . . Gyrus temporalis superior.
$T.^2$ . . . Gyrus temporalis medius.
$T.^3$ . . . Gyrus temporalis inferior.
$t.^1$ . . . Sulcus temporalis primus (parallel sulcus).
$t.^2$ . . . Sulcus temporalis secundus.
F. S. . . Fossa Sylvii.
a. s. . . Anterior free border of the occipital operculum.
e. c. . . External calcarine fissure.
o. . . . Fronto-orbital sulcus.

N.B.—A black dot marks the position of the frontal eminence and also of the parietal eminence in several of the figures.

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Figure 10.—Head of a male child twelve and a-half years old.

Figure 11.—Head of a youth fifteen years old.

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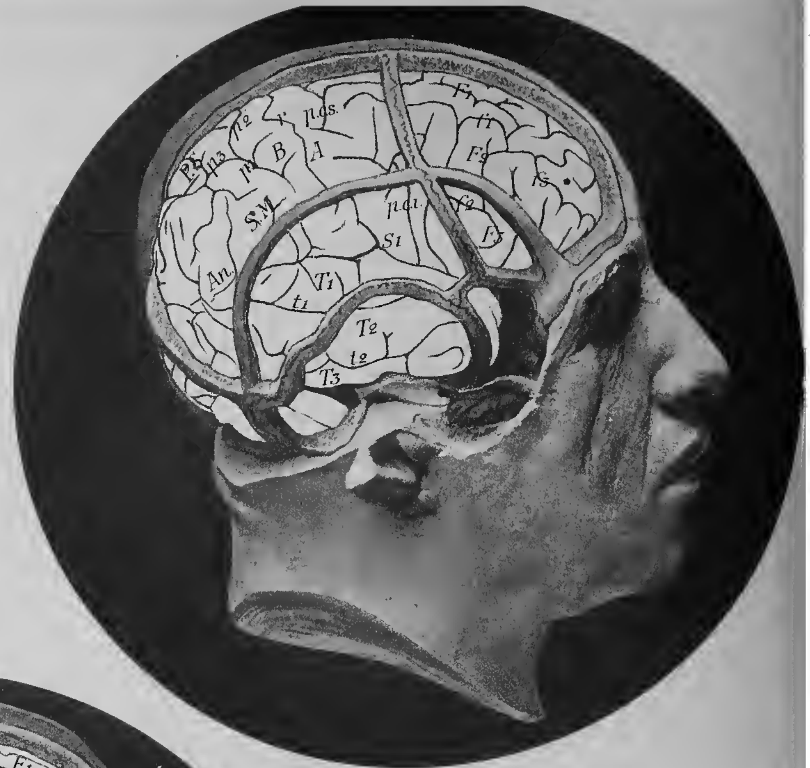

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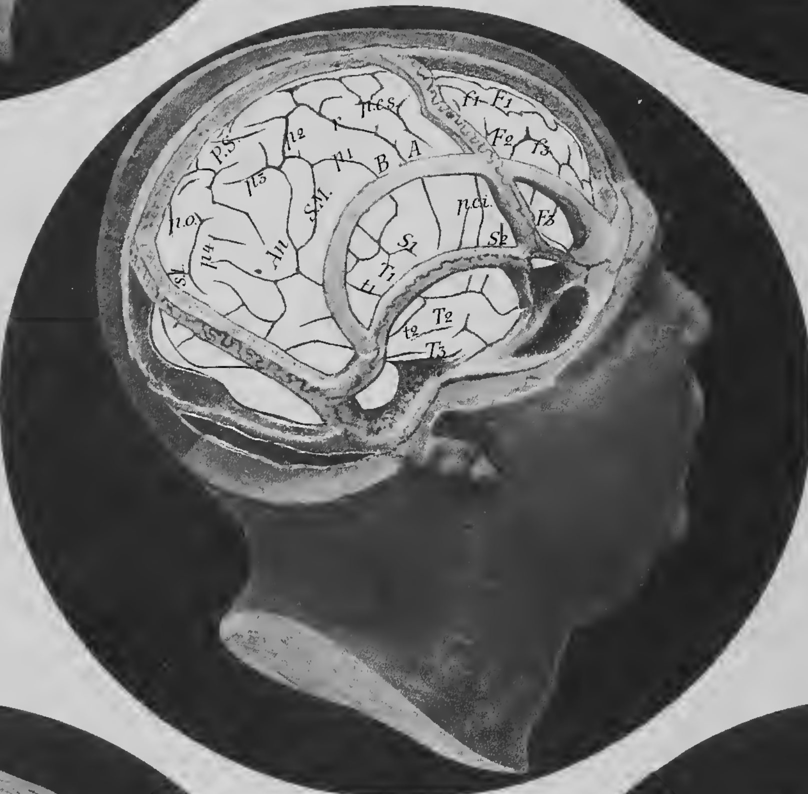

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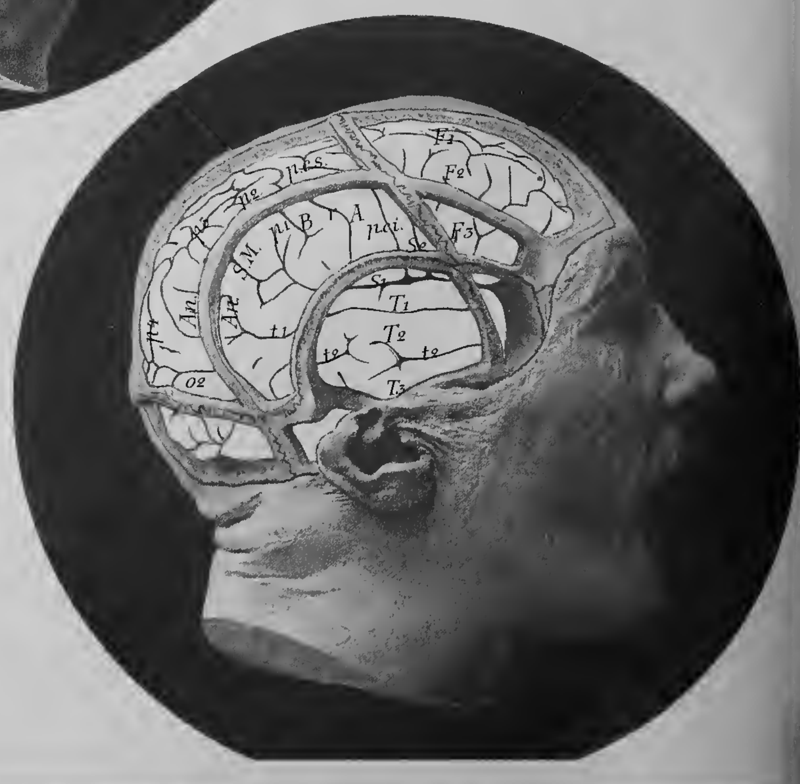

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PLATE VII.

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Figure 12.—Head of an adult male twenty-six years old.

Figure 13.—Head of an adult female thirty-five years old.

Figure 14.—Head of a middle-aged female.

Figure 15.—Head of an elderly female (insane). Note the short spheno-parietal suture, the high squamous part of the temporal bone, and the high temporal ridge.

LETTERING COMMON TO ALL THE FIGURES.

$F.^1$	Gyrus frontalis primus.
$F.^2$	Gyrus frontalis secundus.
$F.^3$	Gyrus frontalis tertius.
$f.^1$	Sulcus frontalis primus.
$f.^2$	Sulcus frontalis secundus.
$f.^3$	Sulcus frontalis medius (Eberstaller).
f.	(in the apes, Pl. VIII.) sulcus frontalis secundus.
p. c. i.	Sulcus præcentralis inferior.
p. c. s.	Sulcus præcentralis superior.
r.	Fissure of Rolando.
A.	Gyrus centralis anterior.
B.	Gyrus centralis posterior.
S. M.	Gyrus supramarginalis.
An.	Gyrus angularis.
P. S.	Lobulus parietalis superior.
p.	Sulcus intraparietalis.
$p.^1$	Sulcus postcentralis inferior.
$p.^2$	Sulcus postcentralis superior.
$p.^3$	Ramus horizontalis (of the intraparietal sulcus).
$p.^4$	Ramus occipitalis (of the intraparietal sulcus).
p. o.	Fissura parieto-occipitalis.
$o.^2$	Sulcus occipitalis lateralis (Eberstaller).
$S.^1$	Ramus horizontalis posterior of the Sylvian fissure.
$S.^2$	Ramus anterior ascendens of the Sylvian fissure. Except in figures 9, 13, and 15, in which "$S.^2$" indicates the sulcus diagonalis.
$T.^1$	Gyrus temporalis superior.
$T.^2$	Gyrus temporalis medius.
$T.^3$	Gyrus temporalis inferior.
$t.^1$	Sulcus temporalis primus (parallel sulcus).
$t.^2$	Sulcus temporalis secundus.
F. S.	Fossa Sylvii.
a. s.	Anterior free border of the occipital operculum.
e. c.	External calcarine fissure.
o.	Fronto-orbital sulcus.

N.B.—A black dot marks the position of the frontal eminence and also of the parietal eminence in several of the figures.

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Rhesus

Baboon

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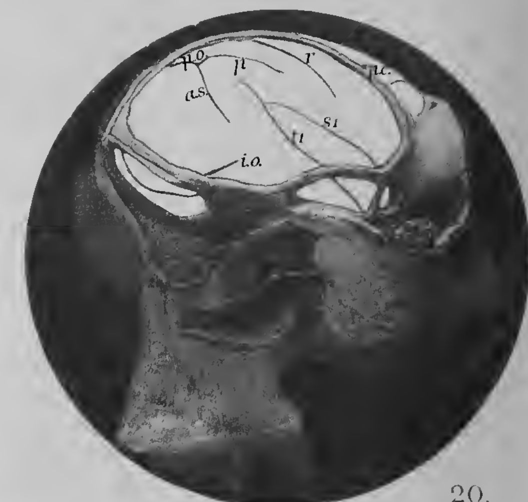

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Cebus

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Orang

Chimpanzee

PLATE VIII.

[The figures in this Plate were drawn upon the stone from photographs of plaster casts of heads in which the brain is exposed *in situ*. Bars of bone are left along the lines of the sutures, and, in some cases, also along the fore part or the whole length of the temporal ridge.]

Figure 16.—Head of an old man aged seventy-five years.

Figure 17.—Head of a centenarian (reputed age one hundred and eleven years).

Figure 18.—Head of *Macacus rhesus*.

Figure 19.—Head of *Cynocephalus anubis*.

Figure 20.—Head of *Cebus capucinus*.

Figure 21.—Head of a male orang-utan six years old.

Figure 22.—Head of a female chimpanzee about three years old.

LETTERING COMMON TO ALL THE FIGURES.

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F.[2] . . .	Gyrus frontalis secundus.
F.[3] . . .	Gyrus frontalis tertius.
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P. S. . .	Lobulus parietalis superior.
p. . . .	Sulcus intraparietalis.
p.[1] . . .	Sulcus postcentralis inferior.
p.[2] . .	Sulcus postcentralis superior.
p.[3] . . .	Ramus horizontalis (of the intraparietal sulcus).
p.[4] . . .	Ramus occipitalis (of the intraparietal sulcus).
p. o. . .	Fissura parieto-occipitalis.
o.[2] . . .	Sulcus occipitalis lateralis (Eberstaller).
S.[1] . . .	Ramus horizontalis posterior of the Sylvian fissure.
S.[2] . . .	Ramus anterior ascendens of the Sylvian fissure. Except in figures 9, 13, and 15, in which "*S.*[2]" indicates the sulcus diagonalis.
T.[1] . . .	Gyrus temporalis superior.
T.[2] . . .	Gyrus temporalis medius.
T.[3] . . .	Gyrus temporalis inferior.
t.[1] . . .	Sulcus temporalis primus (parallel sulcus).
t.[2] . . .	Sulcus temporalis secundus.
F. S. . .	Fossa Sylvii.
a. s. . .	Anterior free border of the occipital operculum.
e. c. . .	External calcarine fissure.
u. . . .	Fronto-orbital sulcus.

N.B.—A black dot marks the position of the frontal eminence and also of the parietal eminence in several of the figures.

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Figure 21.—Head of a male orang-utan six years old.

Figure 22.—Head of a female chimpanzee about three years old.

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Rhesus

Baboon

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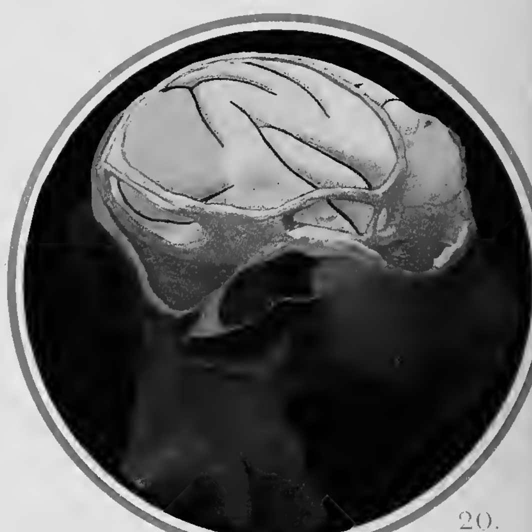

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Cebus

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